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Final Report
by

T. Enwald, Tampella Power Inc.

M. E. Ball SaskPower

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Tampella Power

SaskPower

POPLAR RIVER POWER STATION

LIFAC DEMONSTRATION UNIT

TEST REPORT

21.3.1991

by

T. Enwald
Tampella Power Inc.

and

M.E. Ball
SaskPower

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ABSTRACT

Tampella Power and Saskatchewan Power Corporation (SaskPower) have carried out a joint project to design, manufacture and test LIFAC® desulfurization process in full scale at SaskPower's Poplar River Power Station. LIFAC® is an advanced limestone injection process with flue gas humidification reactor. The process was extensively tested at Poplar River Power Station to evaluate the effect of different process conditions on SO_2 removal. The demonstration unit was commissioned and phase I testing completed in 1990. Phase II testing will take place in 1991 and addresses the operability of LIFAC® including the effect on plant operations and auxiliaries.

LIFAC® indicates a trademark of Tampella Power Inc.

1 INTRODUCTION

Tampella Power Inc. (Tampella) and Saskatchewan Power Corporation (SaskPower) have carried out a joint project to design, manufacture and test LIFAC® desulphurization process at SaskPower's Poplar River Power Station near the town of Coronach in Southern Saskatschewan.

LIFAC® is a dry/semidry flue gas desulphurization process developed by Tampella, Finland and marketed in Canada by the Canadian subsidiary, Tampella Power Canada Inc., Regina, Sask. LIFAC® process is installed in full scale at SaskPower's Poplar River Power Station unit #1.

The objective of the demonstration unit is to allow SaskPower to evaluate the suitability of LIFAC® to power plants burning low sulphur lignite coal. At the same time Tampella has the opportunity to demonstrate LIFAC® for the North American market.

LIFAC® includes limestone injection into furnace and reactivation of unreacted calcium by humidification of flue gas in a separate reactor. Limestone is transported pneumatically to furnace as a dry powder. A portion of sulphur dioxide is captured in furnace. This is usually limited to less than 40 % at economically feasible limestone feed rates. Therefore the humidification step adds

considerably to sulphur dioxide capture; most of the capture is achieved in the humidification reactor.

At Poplar River Power Station 50 % of unit #1 flue gas is humidified. Limestone is injected to upper part of furnace just below superheater level. Fly ash from electrostatic precipitators can be recycled to reactor inlet duct.

Process design was carried out in July-November 1989, construction took place in April-August 1990. Parametric testing was done during five weeks in October-December 1990. The results of the parametric testing are documented in this report. Phase II testing, a two month operating period to assess the impact on plant operations and auxiliaries started February 6th 1991 and will be completed in early April 1991.

2 SYSTEM DESCRIPTION

The LIFAC® demonstration unit at Poplar River Power Station consists of limestone storage and feed equipment, humidification reactor and related equipment, ash handling equipment and ash recycle equipment. These process equipment are described in the following subsections. Limestone nozzle system design is discussed in detail in appendix A. Also a description of PRPS unit #1 boiler is enclosed in appendix A. Figure 1 describes the connections of LIFAC® to the existing

ducting of the power plant. Figures 2 and 3 describe process equipment arrangement.

2.1 Limestone storage and feed equipment

Limestone is delivered to site pulverized and stored there in a 250 m^3 silo. The silo has aerated bottom and a ventilation system with baghouse to control silo pressure during unloading of limestone trucks.

Limestone feedrate to furnace is controlled by a rotary feeder with variable speed drive at silo discharge. The rotary feeder feeds limestone to a weigh belt which is running at constant speed. Limestone feedrate is measured by load cells on the weigh belt. The weigh belt takes limestone to a screw pump. At the outlet of the screw pump limestone is mixed with transport air which blows it to the furnace. Any limestone spilled from the weigh belt is taken to the screw pump by a scavenger conveyor below the weigh belt.

Limestone is injected to furnace using six nozzles, three at both side walls of the furnace at elevation 804334. Material leaving velocity at the nozzle is 47 m/s. Each limestone nozzle is surrounded by a booster air nozzle. Booster air is used to improve the penetration of sorbent into furnace. Air velocity in booster air nozzle is 137 m/s. Limestone

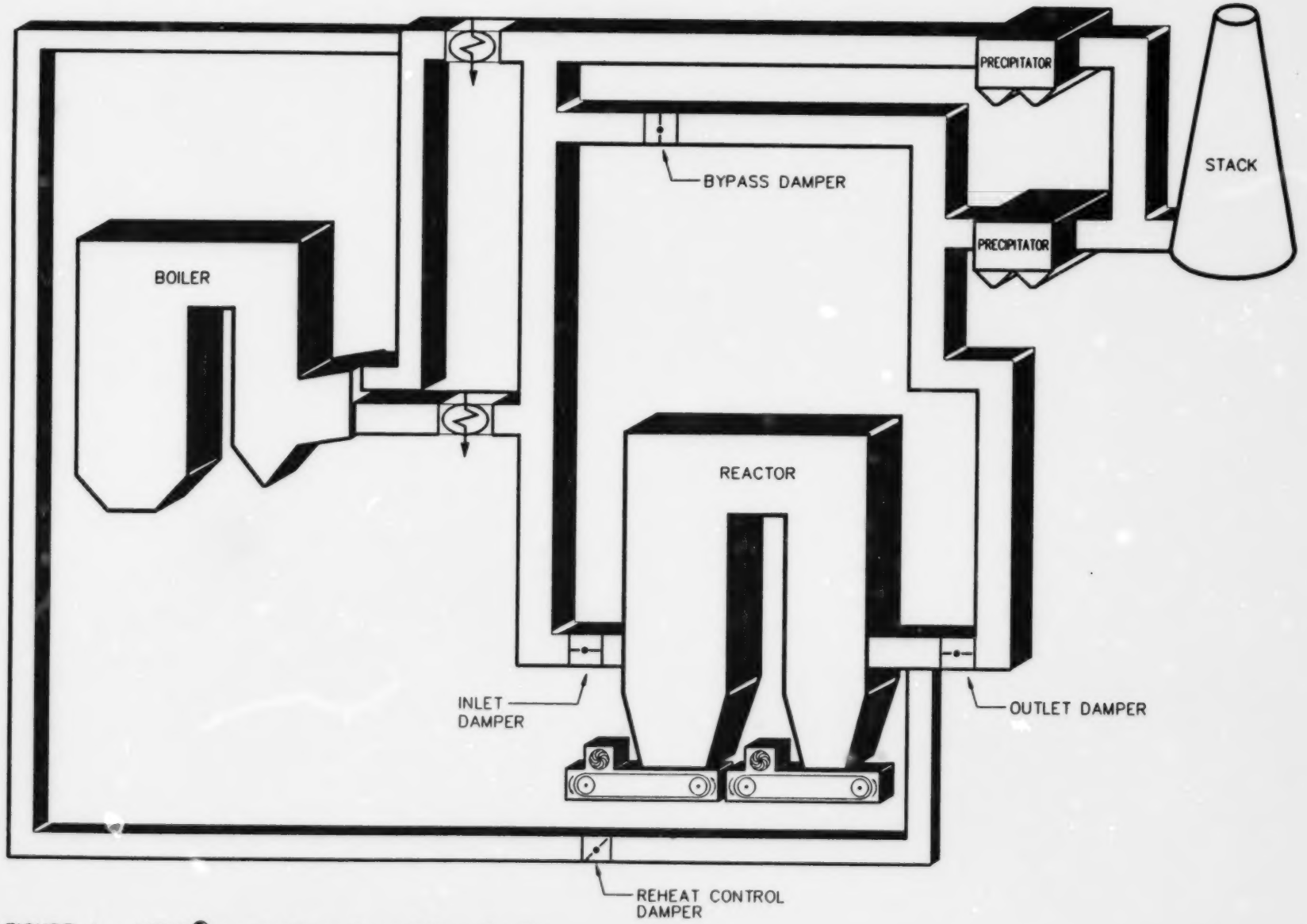


FIGURE 1. LIFAC® connections to existing ducting.

transport air and booster air flows were kept constant regardless of boiler load changes.

2.2 Humidification reactor

Humidification of flue gas takes place in a reactor chamber which is located between air preheaters and electrostatic precipitators. Flue gas is humidified by water sprays from dual fluid nozzles. Water evaporates in reactor thus cooling the flue gas to a near water dew point temperature. Flue gas from the reactor is reheated by about 15°C before entering the precipitator, using hot flue gas taken upstream from te primary air heater.

2.3 Ash handling

Reactor walls are equipped with vibrators which drop ash deposits to the reactor bottom. Reactor bottom conveyors take ash to a tank where it is slurried. Ash slurry is then pumped to the plant ash transfer tank from where it is further pumped to a sealed lagoon together with fly ash.

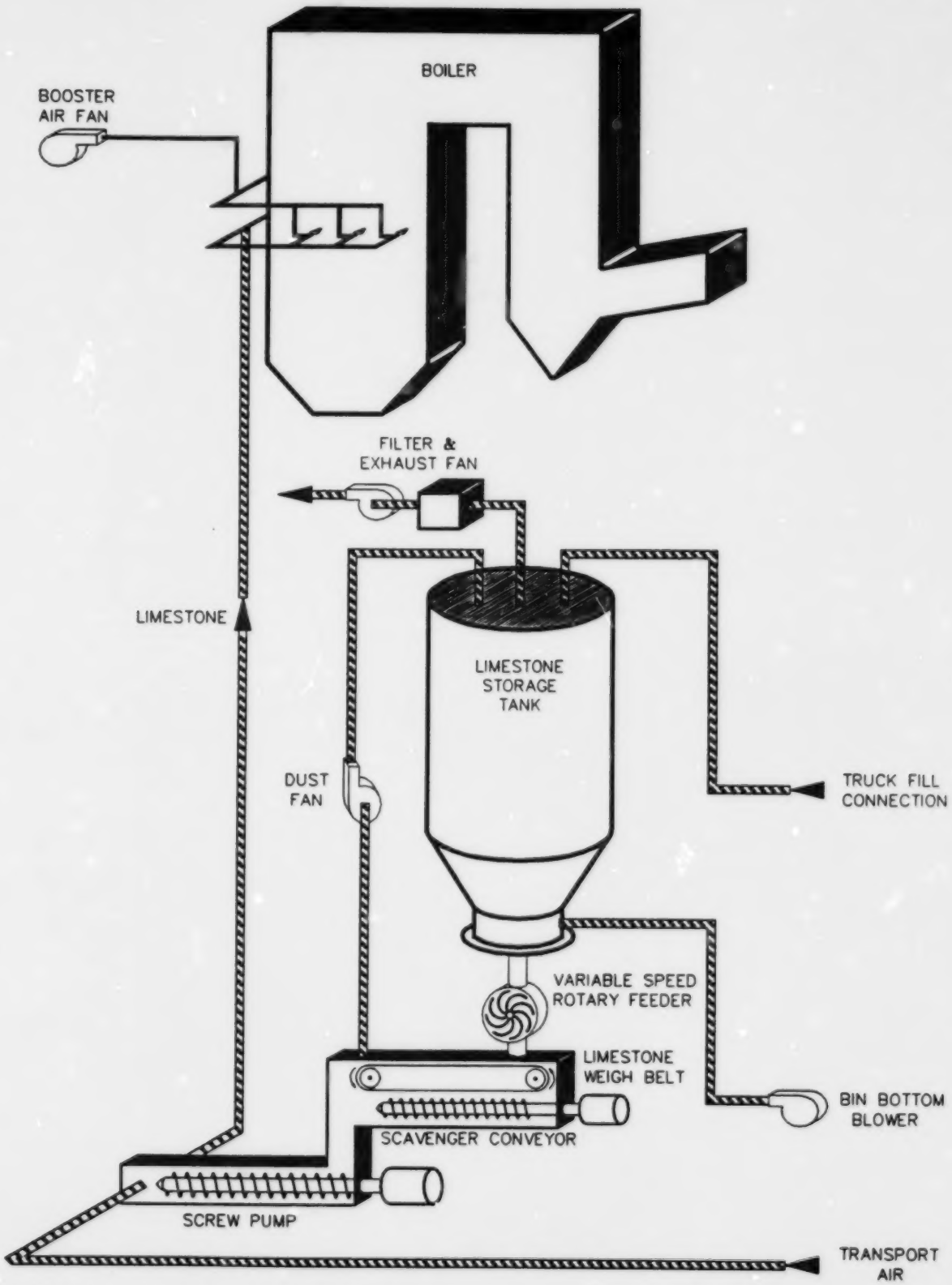


FIGURE 2. Limestone injection system.

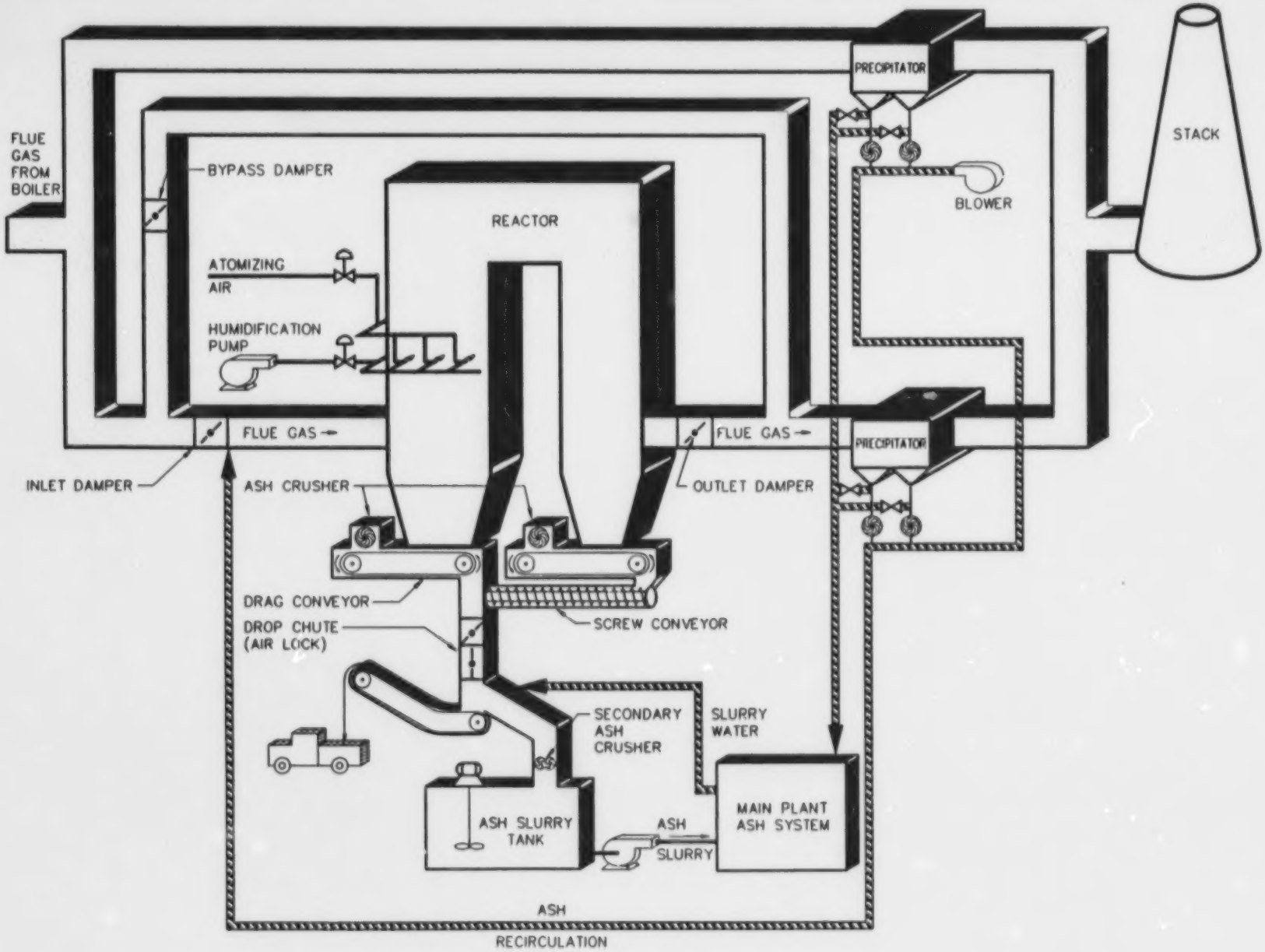


FIGURE 3. Humidification system with ash handling and recycle.

2.4 Recycle equipment

Unit #1 electrostatic precipitators' first field hoppers were equipped with rotary feeders which can feed ash from the hoppers to a pneumatic transport line where it is blown to reactor inlet duct. The original ash removal system remains in place and in service so that any ash which is not recycled goes normally to the plant ash system.

3 OBJECTIVES OF PARAMETRIC TESTING

The objective of parametric testing was to investigate the effect of following parameters on sulfur dioxide removal efficiency:

- Calcium/sulfur ratio
- Reactor outlet temperature approach to dew point
- Boiler load
- Excess air at injection elevation
- Booster air
- Limestone injection angle
- Recycle of fly ash to reactor
- Furnace temperature

Another objective of parametric testing was to determine the set of operating parameters for which optimum performance of

the LIFAC® system is achieved and to measure SO_2 reduction as a function of Ca/S ratio at the optimum operating point.

4 LIMESTONE SUPPLY AND HANDLING

Test sorbent for this test series was a calcitic limestone from the Mafaking deposit in north western Manitoba. The limestone was hauled by rail from the quarry to the Inland Sement plant in Regina, as part of the cement plant's normal supply. At the Inland plant, the limestone was pulverized in a ball mill in batch operations as required to maintain reserve in the plant's 1000 Mg storage tank. The pulverized limestone was shipped to Poplar River in "B" train truck units, with one load every 3 or 4 hours on average throughout the tests.

Pulverization of limestone during this testing was done with a constant mill setting, and the product was very consistent in both size distribution and chemical composition. A typical analysis is shown in table I, more detailed results are in appendix B.

Bench scale tests of the Inland Cement product indicated good to superior characteristics for sorbent injection - see appendix I.

Table I Sorbent properties

% Moisture	< 0.25
% $CaCO_3$	95.48
% SiO_2	1.26
% Al_2O_3	0.89
% Fe_2O_3	0.26
% MgO	0.78
% SO_3	0.29
% Na_2O	0.05
% K_2O	0.20
% Undetermined	≥ 0.54
Particle size	90 % < 15.5 μm
	50 % < 3.9 μm
	10 % < 1.5 μm

In phase II testing, limestone size distribution will be changed and limestone from a different source will be tested.

Limestone mass flow was measured with a weigh belt. The flowrate measurement was found to go out of calibration during operation as limestone was collected on the weighing system. This caused base load which was added to the actual mass flow. Several measures were taken to eliminate this problem by keeping the system clean. However, it was found that the accuracy of the weighing system could be seriously deteriorated with minor buildup of limestone which could not be totally eliminated during testing. Therefore it was decided to use a separate scale to check the flowrate. The procedure was as follows: The belt was stopped, a 1 m long section of the belt was marked and limestone was shoveled out of the belt. This sample was weighed and the flowrate was calculated using the belt speed. Figure 4 shows the dependency between sampled flowrate and the flowrate given by

weigh belt. A correction factor for the relationship between measured flow and setpoint was used to determine the actual flow. This eliminated part of the uncertainty about the flow rate seen in figure 4.

After completition of phase I tests, a scavenger conveyor was added and the belt weigher ventilation was revised. These modifications alleviated the measurement problems.

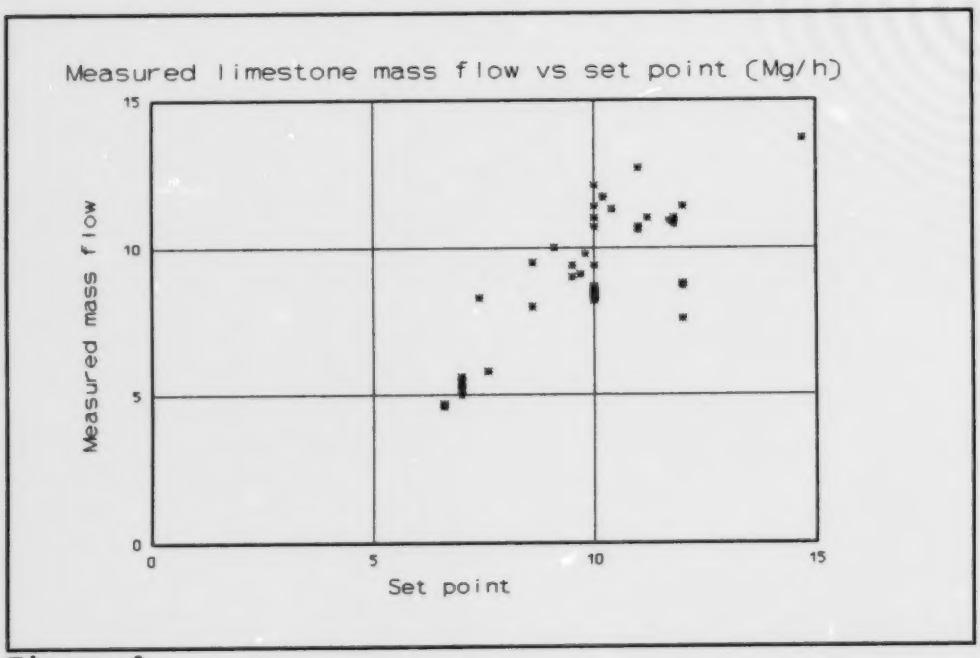
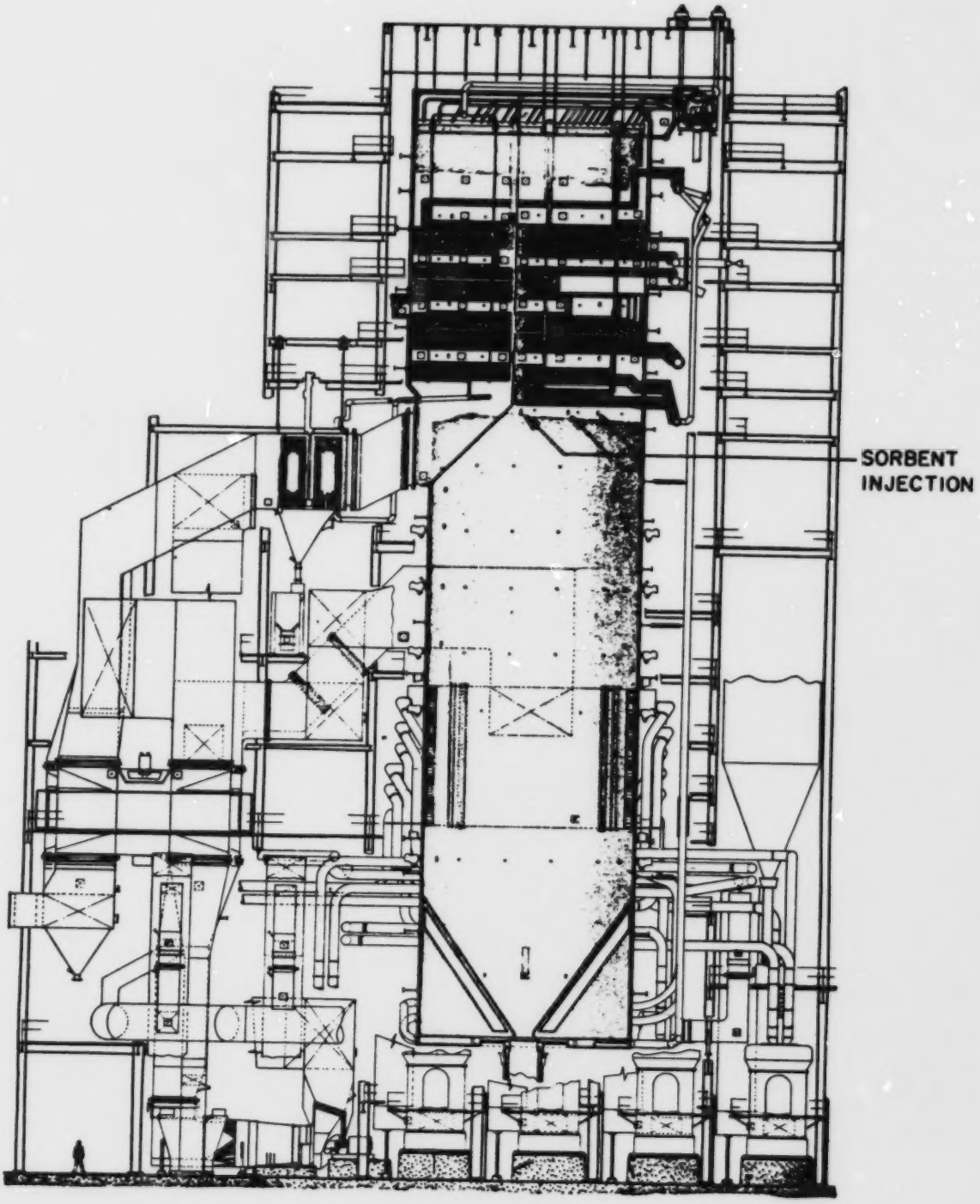


Figure 4


SORBENT
INJECTION

5 COAL SAMPLING SYSTEM

Coal from the nearby Poplar River Mine is delivered by rail to the plant's 20000 Mg coal storage tressel. Rotary plows at the bottom of the tressel feed the coal on "as-required" basis onto a belt system which elevates the coal to either of the two units. A scraper conveyor sequentially fills the six bunkers on each unit. Coal flows from each bunker outlet through a Stock volumetric feeder to a pulverizer, then to the furnace. Normally, five of the six feeders/pulverizers are in service.

The bunkers typically hold adequate coal for six hours of full load operation.

Coal sampling for normal plant operations is based on "stopped belt" samples taken during filling of the bunkers. Because of the bunker storage time and filling method, stopped belt sampling offers no possibility of following the short term quality variations demonstrated by the changing stack SO_2 values shown in figure 6, so the system illustrated in figure 5 was developed.

Coal discharging from the belt of the Stock volumetric feeders was sampled with a cross stream scoop manufactured by the Stock Equipment Co. One 2 kg sample was extracted each 3 minutes, sequencing through the five operating feeders. The feeder samples were fed to a Holmes 401 XL laboratory crusher

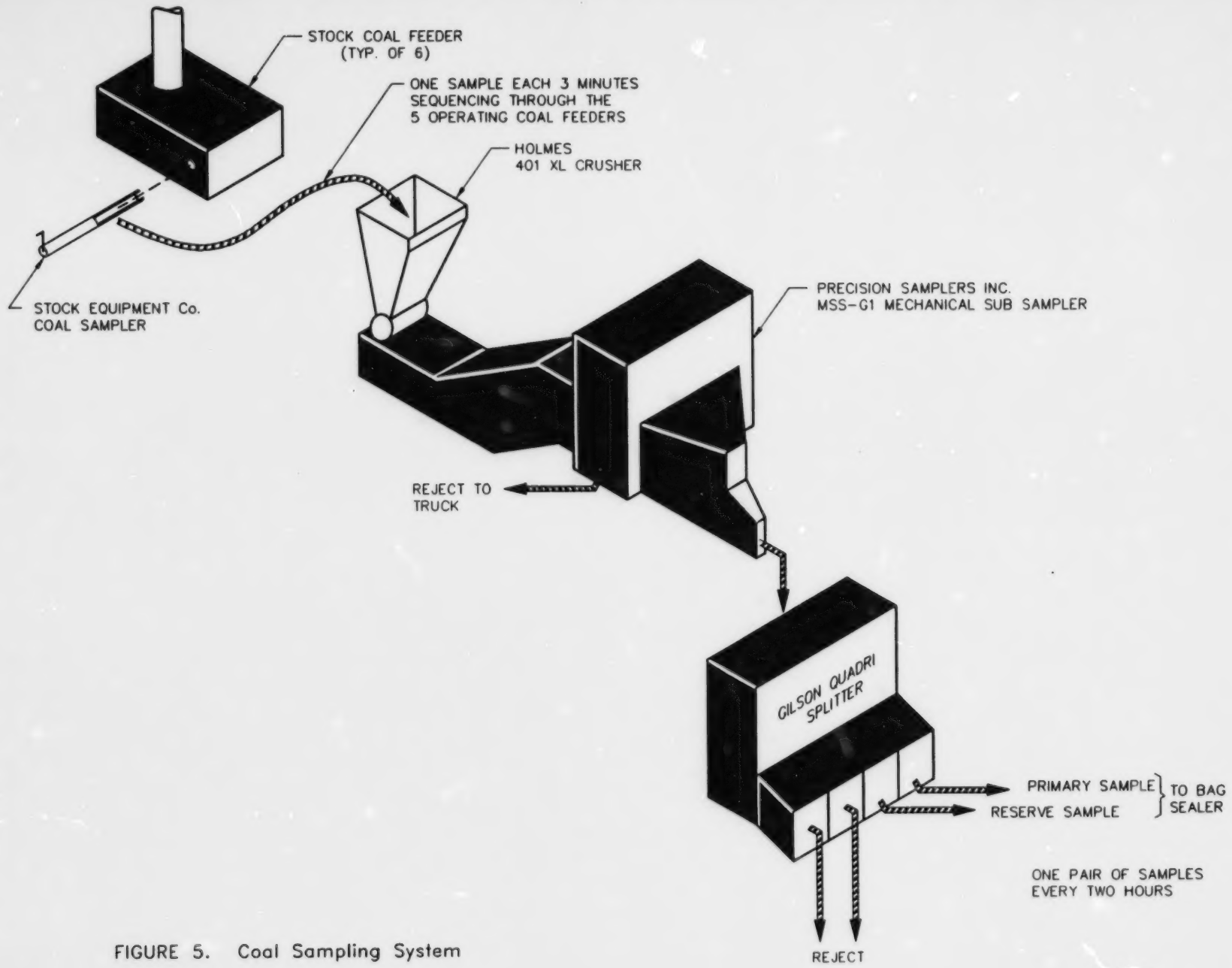


FIGURE 5. Coal Sampling System

for size reduction. The stream from the Holmes crusher was then subsampled by a Precision Samplers Inc. MSS-G1 mechanical subsampler. The subsample was divided in a Gilson Quadri Splitter, and primary and reserve samples saved in heat sealed plastic bags. The process yielded one sample pair per two hours.

Analysis results are in appendix C. In many instances, furnace SO_2 calculated from the coal sample analyses followed observed values with no sorbent flow. However, in most cases, coal samples were taken while sorbent was flowing to the furnace, so the number of furnace measurement comparisons is small. In 7 instances where disagreement was noted, the reserve sample was analyzed. In most of these cases no better agreement was reached with the reserve sample. This could be an indication of the nonhomogeneous coal quality affecting the sample representativity in spite of the elaborate sampling method used. An average analysis of coal samples is in table II.

6 FLUE GAS MONITORING

Flue gas was continuously analyzed for sulfur dioxide and oxygen in reactor inlet and outlet ducts using two Monitor Labs model 8850 analyzers with EPM diluting probes. Oxygen was measured with two Westinghouse ZrO_2 analyzers. Oxygen

Table II Average test coal analysis

Dry analysis:	
% C	55.9
% H_2	4.3
% O_2	17.4
% S	1.0
% N_2	0.7
% Ash	20.9
% Moisture	37.7

Calorific heating value 13.5 MJ/kg

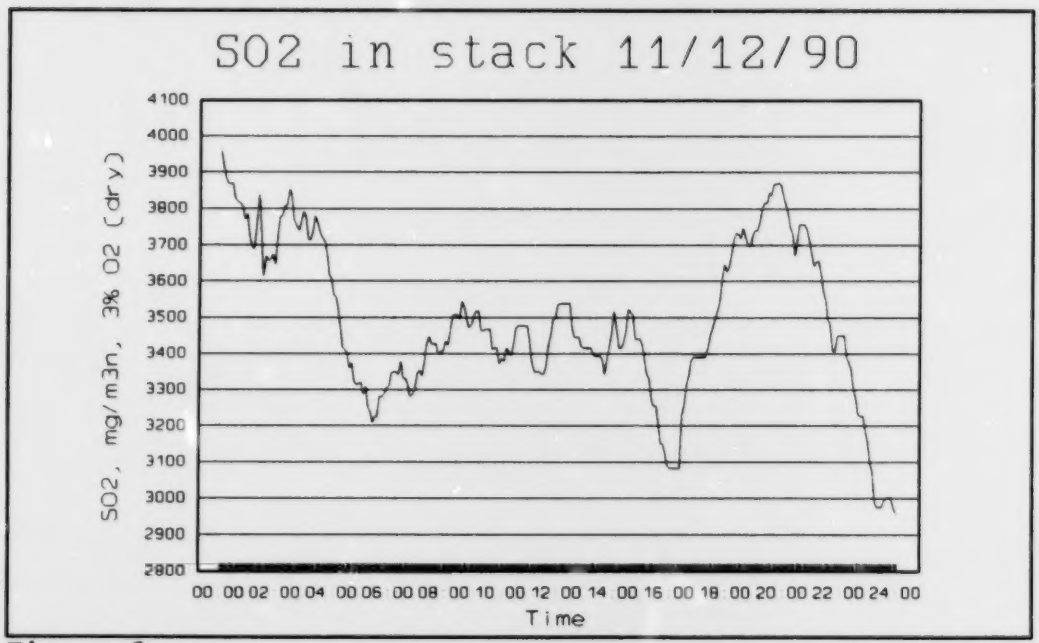


Figure 6

analyzer probes were located near SO_2 probes. SO_2 and O_2 were measured on wet basis and SO_2 concentration was corrected to 6 % oxygen in wet gas when expressed in units $mgSO_2/m^3_n$.

To validate the operation of sulfur dioxide analyzers SaskPower's TS&R personnel installed temporary extractive SO_2

analyzers at the air heater inlet and at the reactor outlet. Each extraction system included a heated sample probe and filter, and a water extraction unit.

Readings of the different analyzers compared well after some modifications were made at reactor outlet Monitor Labs analyzer's sample probe. Conditions at reactor outlet are very severe for any kind of sulfur dioxide analysis system due to high humidity, high ash concentration and near approach to water dew point. Both systems used did demand frequent maintenance to give reliable readings. Some test data had to be neglected because ash was collected in the probe which caused SO_2 absorption to the ash inside probe.

The trend on the following page shows all four SO_2 analyzer's readings during a test day with humidification on. The four trends are (from up to down where marked with a vertical line): TS&R analyzer at air heater inlet (TS&R 1), project analyzer at reactor inlet (Project 1), TS&R analyzer at reactor outlet (TS&R 2) and project analyzer at reactor outlet (Project 2). All readings are in ppm and oxygen and moisture contents in sample gas of different analyzers vary, so corrections must be made when comparing the traces. As an example, the readings at 12:00 pm are normalized to 6 % oxygen (wet) and dry flue gas in table III.

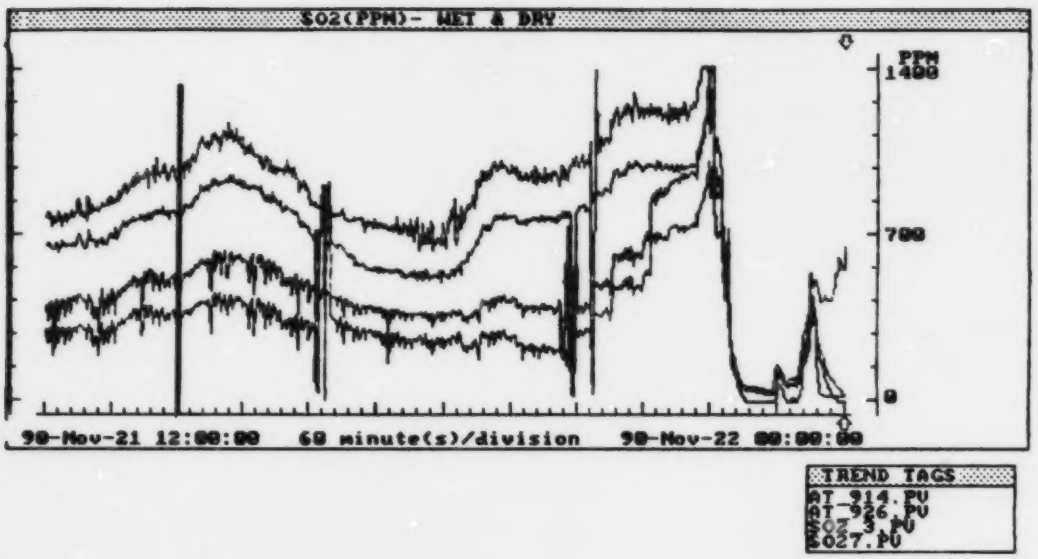


Table III

Analyzer	Reading ppm	Moisture vol-%	Oxygen vol-%	Normalized reading ppm
TS&R 1	956	18.5	1.7	735
Project 1	789	18.5	2.5	785
TS&R 2	500	22.6	3.4	426
Project 2	356	22.6	3.4	392

Note TS&R analyzers measure dry and project analyzers wet gas

7 FURNACE MODELING

Prior to the design of the limestone injection system a model study was conducted by Energy and Environmental Research Corporation (EER), California. This study consisted of boiler heat transfer modeling, furnace sulfation modeling, sorbent distribution and isothermal physical flow modeling. As a result of the study, design specifications were given for the limestone injection system. Limestone nozzle location and number, injection velocity and nozzle configuration were designed according to the model study. A sulfation model was used to predict the SO_2 removal in furnace achieved with the recommended design. A summary of design results is in appendix A.

The predicted temperature in the injection zone (EL 804334) at 300 MW load with limestone injection and booster air was 1230°C, at 225 MW load 1170°C (see modeling results in figure 4-7 in appendix A). The average temperatures measured during LIFAC® testing in 1990 were 1163°C at full load and 1174°C at 200 MW load, both measured during limestone injection with booster air. Without booster air the average temperature measured at 300 MW load was 1299°C, compared to the predicted 1280°C. At 200 MW load without booster air an average of 1193 °C was measured.

The sulfation model of EER predicted 16 to 19 % SO_2 removal in furnace without booster air at Ca/S ratio 2 at 100 % load.

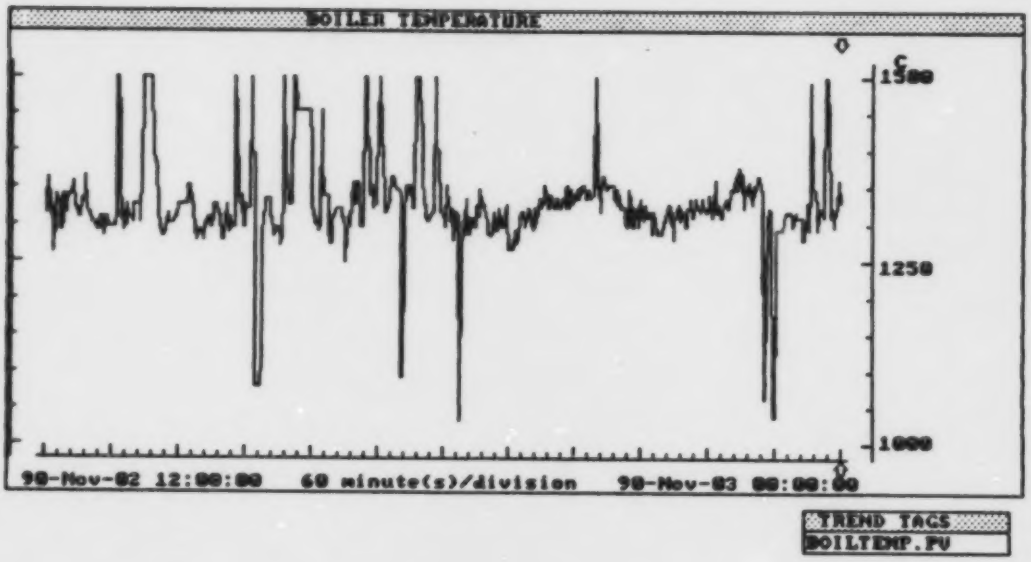
This corresponds to the use of transport air flow of 0.6 % of total combustion air flow. By using booster air the total transport air flow is increased to 4 % of combustion air. This was predicted to increase SO_2 removal in furnace to 24 %. As described in section 8.1.1 the achieved SO_2 removal at 300 MW load was 14 % at Ca/S ratio 2 and booster air flow had no significant effect on SO_2 removal.

At 75 % load (225 MW) the model prediction was 24 % removal without booster air and 25 % with booster air. At 200 MW load the achieved removal was 22 % with Ca/S ratio 2.

8 FURNACE TEMPERATURE MEASUREMENT

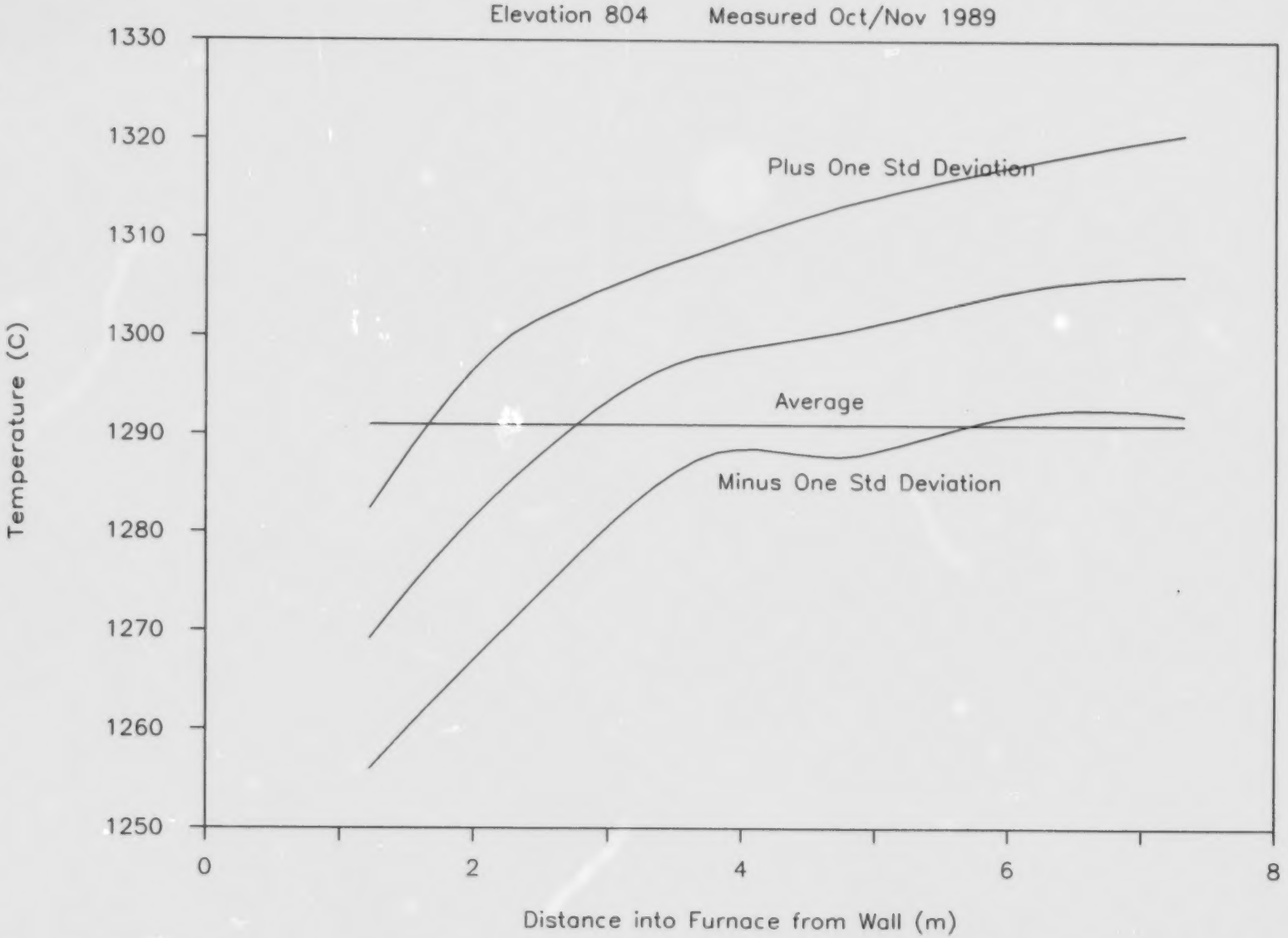
A single path acoustic pyrometry system was installed on the furnace at the sorbent injection elevation. After some commissioning difficulties, the system was put into service and gave bulk furnace temperatures consistent with those observed with a high velocity thermocouple (HVT). Unfortunately, noise from sorbent transport air and from booster air each overwhelmed the acoustic signal from the pyrometry system, and no measurements could be obtained during sorbent injection. Since no other useful location was available for the acoustic pyrometry system, the equipment was returned to the manufacturer. A furnace temperature trend, without sorbent injection, is plotted below. The trend

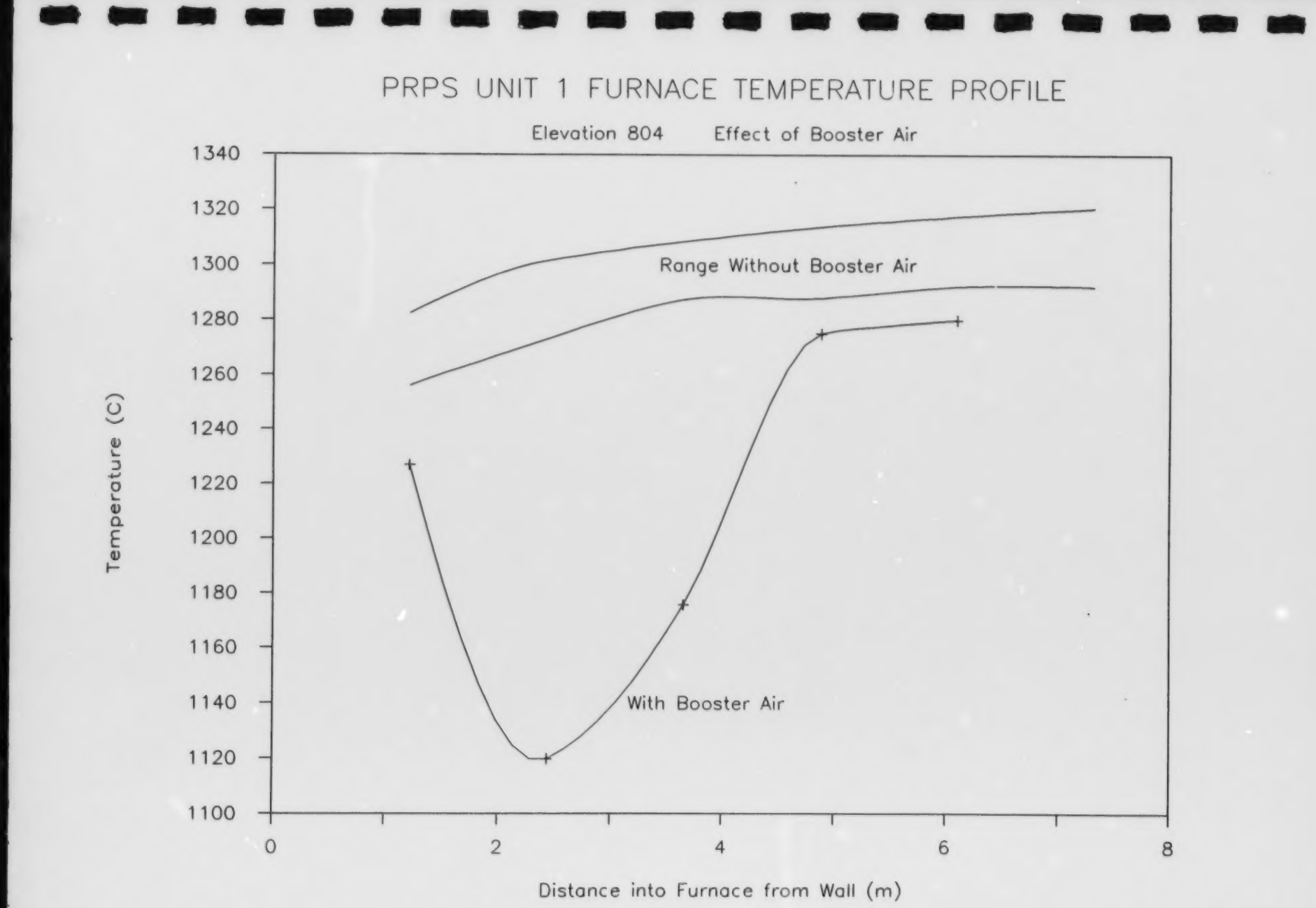
demonstrates the variations in furnace temperature during normal "steady state" boiler operation.



Early investigations by HVT showed that the furnace temperature profile in the injection plane was flat once the probe was more than 8 feet into the furnace. With sorbent injection only, no change in the profile was observed, however, with booster air the gas temperature was significantly depressed for 12 or 16 feet into the furnace.

PRPS UNIT 1 FURNACE TEMPERATURE PROFILE




PRPS UNIT 1 FURNACE TEMPERATURE PROFILE
Elevation 804
Effect of Booster Air
Range Without Booster Air
With Booster Air
Temperature (C)
1340
1320
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
0
2
4
6
8
Distance into Furnace from Wall (m)

Where single values are reported for furnace temperature, it is the maximum of 3 sequential readings obtained with the HVT inserted 12 feet into the furnace.

9 PARAMETRIC TESTING

Data used to prepare results presented in this chapter is shown in appendix D.

8.1 Ca/S ratio

Injected Ca/S ratio was calculated from limestone mass flow, limestone $CaCO_3$ content, coal mass flow and coal sulphur content as follows:

$$Ca/S = \frac{\dot{m}1 \times \frac{CaCO3}{100} \times 32}{\dot{m}2 \times \frac{S}{100} \times 100} \qquad (1)$$

where
- $\dot{m}1$ = limestone mass flow, Mg/h
- CaCO3 = $CaCO_3$ content in limestone, w-%
- $\dot{m}2$ = coal mass flow, Mg/h (wet)
- S = sulphur content in wet coal, w-%

Coal sampling analysis results were used to determine coal sulphur content and moisture when available. However, during part of testing no coal samples were taken. For those tests the average coal analysis in table II was used for calculation of Ca/S ratio. Coal mass flow was calculated from turbine heat rate using turbine design data, and boiler efficiency determined by testing conducted immediately prior to beginning of the test series (see appendix H).

8.1.1 Furnace

The effect of injected Ca/S ratio on SO_2 reduction in furnace is shown in figure 7. Regression analysis was made using Ca/S ratio as the only variable. Data at 300 MW and 200 MW was analysed separately because a change in boiler load does change furnace temperature, excess air level and gas residence time in furnace which all effect SO_2 removal.

As expected, the reduction of SO_2 increased with increased Ca/S ratio. At 300 MW load the SO_2 reduction in furnace was remarkably low compared to reduction at 200 MW or results predicted in the EER sorbent injection modeling research (appendix A).

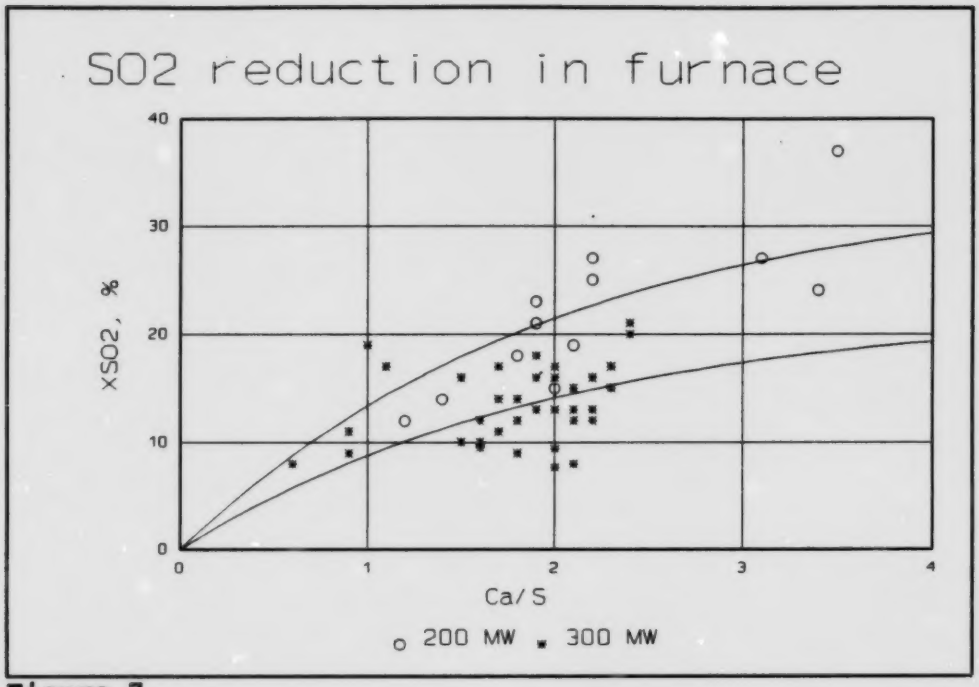


Figure 7

8.1.2 Humidification

As in furnace, SO_2 capture in humidification reactor increased with increased Ca/S ratio. Figure 8 shows reactor performance data at two different approach temperatures (ΔT) at 300 MW boiler load with ash recycle from all hoppers. Figure 9 has the corresponding information without ash recycle. Regression analysis was made with Ca/S ratio and ΔT as independent variables. Regression analysis was made separately for data sets at different boiler loads and ash recycle modes.

The effect of Ca/S ratio at 300 MW boiler load is shown in figures 10 and 11 using regression analysis results for different reactor outlet temperature approaches to dew point.

Regression curves in figures 10 and 11 are based on same data as is in figures 8 and 9, correspondingly.

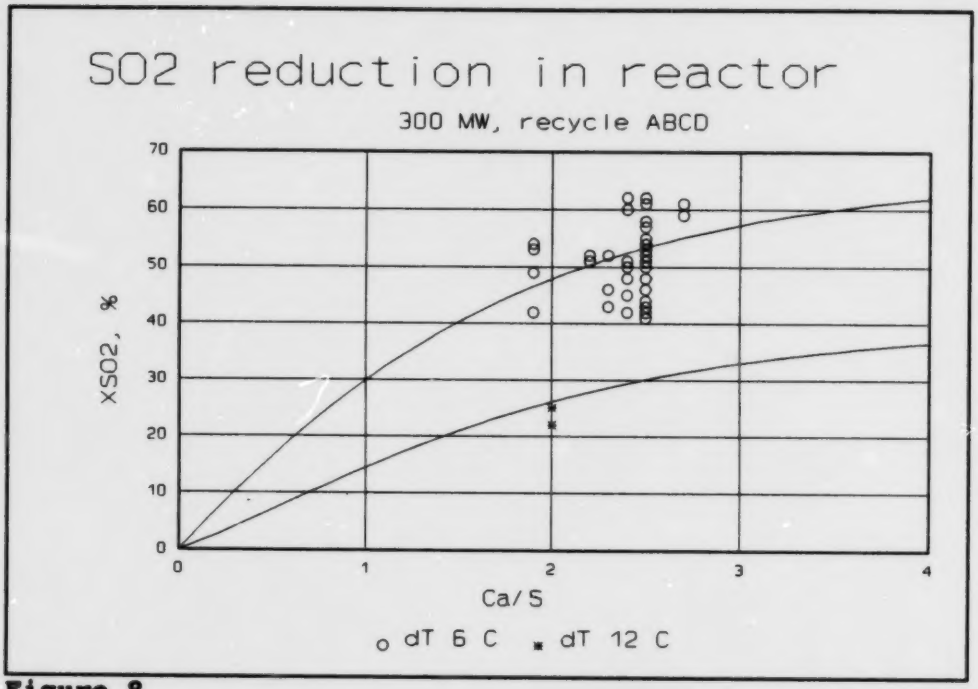


Figure 8

Figures 12 and 13 describe reactor performance at 200 MW boiler load without recycle. All available data at 200 MW load with recycle is shown in figure 14.

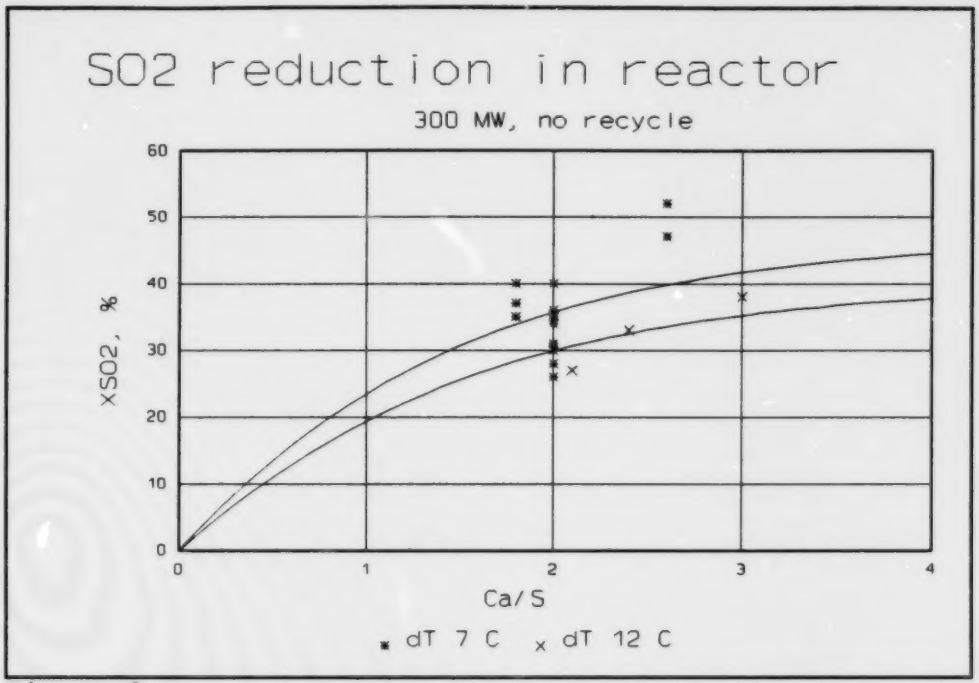


Figure 9

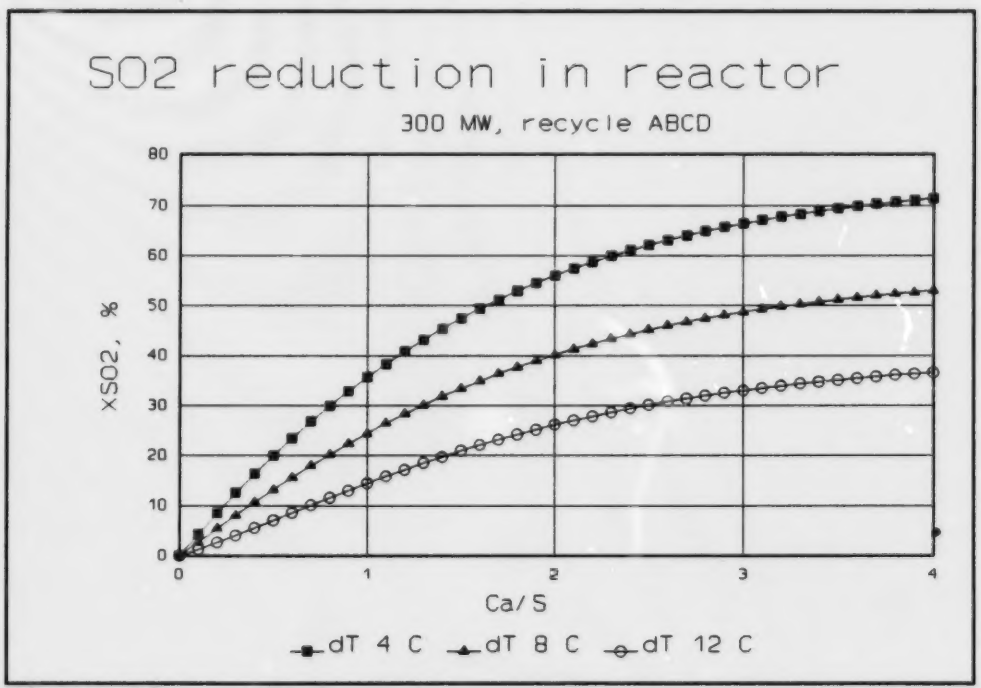


Figure 10

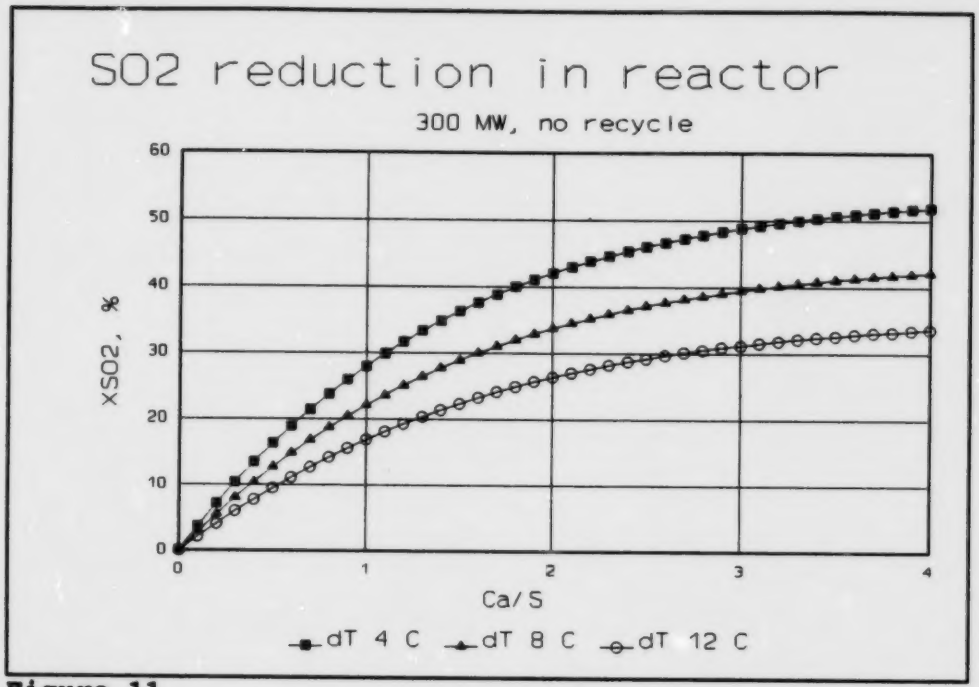


Figure 11

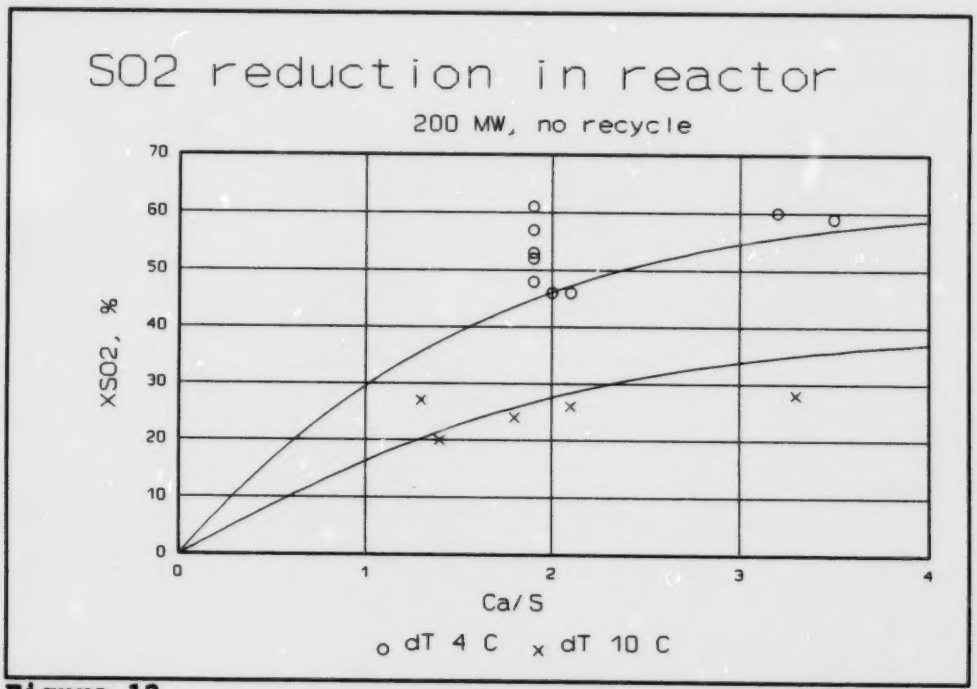


Figure 12

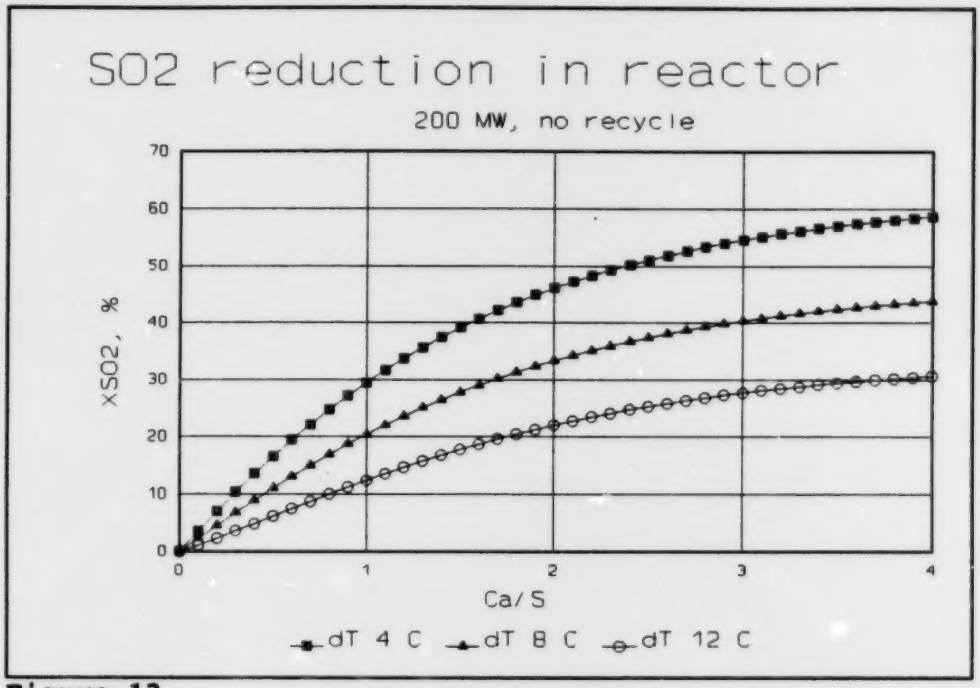


Figure 13

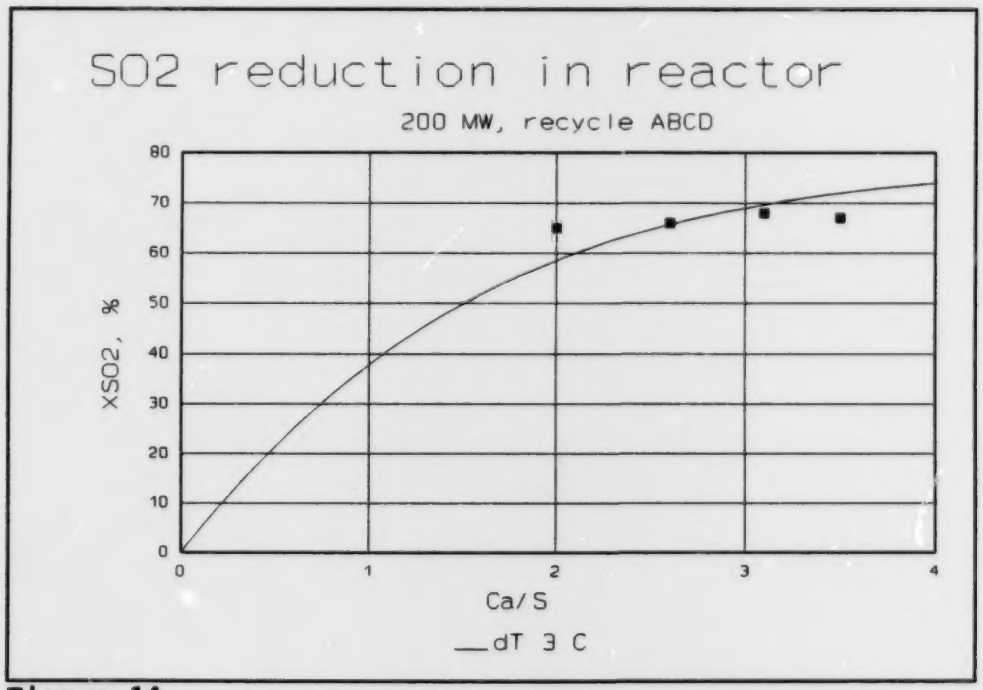


Figure 14

8.2 Furnace temperature and excess air

Furnace temperature is known to have an effect on furnace SO_2 removal. Figure 15 shows SO_2 removal against furnace temperature using data from the normal temperature variations at 300 MW load. The figure also shows that the data is widely dispersed.

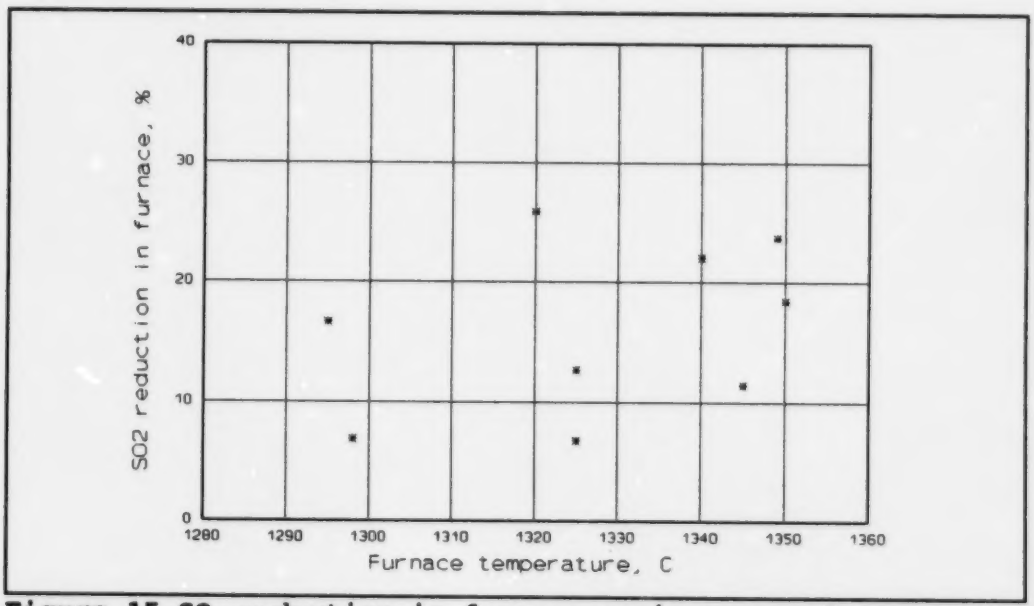


Figure 15 SO_2 reduction in furnace against normal temperature variations at 300 MW load with Ca/S ratio 2 and normal excess air level.

To obtain more direct correlations, unit load was dropped to 180 MW thereby permitting manipulation of the burner tilts. All operating parameters were then held constant except desuperheater sprays and burner tilts. As the burners were manually ramped from -30 degrees to +5 degrees, the furnace gas temperature changed approximately 50°C, an insignificant

change compared to the normal furnace temperature variations (see graph in section 8).

Larger temperature variations were possible by changing excess air and by dropping boiler load. These variations were also accompanied by changes in free oxygen and furnace residence time, both factors known to influence furnace SO_2 absorption.

The combined effect of furnace temperature and excess air was studied by increasing the free oxygen from the normal 2.3 % at 300 MW load to 4.0 %. At 200 MW load the corresponding change was made by decreasing oxygen from 4.0 % to 2.3 %. These changes caused furnace temperature to drop by 120°C at 300 MW load and increase by 60°C at 200 MW load. The resulting changes in furnace exit SO_2 concentration are recorded in table IV where is also an estimate of the change in furnace SO_2 removal. As coal analysis was not available for these tests, the actual change in SO_2 removal could not be determined. In stead, an estimate based on average coal analysis and average SO_2 removal (figure 7) in furnace was used.

Attempts were made to apply regression analysis to separate the effects of excess air and furnace temperature. Excess air, furnace temperature and Ca/S ratio were used as independent variables on SO_2 removal in furnace. Excess air and furnace temperature could not be changed separately which

Table IV The combined effect of furnace temperature and excess air on furnace SO_2 removal with a change in excess air from 2.3 % to 4.0 % O_2

Test Date	Time	$\Delta T_{Furnace}$ °C	Load MW	ΔSO_2 %	X^{*}_{SO2} avg %	X^{**}_{SO2} estim %
1-Dec-90	15:15	165	300	17.0	14	29***
2-Dec-90	02:30	120	300	5.3	14	19
2-Dec-90	13:45	120	300	7.5	14	20
5-Dec-90	02:30	60	200	5.7	22	26
8-Dec-90	04:50	58	200	13.9	22	33

Notes

* From figure 7, Ca/S ratio 2
** Using 2000 mg/m^3_n as SO_2 baseline
*** Sootblowing during testing

resulted in a relationship that was found not to be significant, and had to be neglected.

No changes could be observed in reactor SO_2 removal when excess air and furnace temperature changes were made.

8.3 Injection angle

The effect of limestone nozzle angle was tested by changing the nozzle angle from -15 to -30 degrees from horizontal plane. This was done only at 300 MW load as reduced load was available only for a limited time. Booster air flow was repeatedly switched on and off during these tests while limestone mass flow rate was kept constant. Nozzle angle was changed 25 times. No change in SO_2 level after furnace could

be noticed that would clearly have been caused by a change in nozzle angle. Different combinations of nozzle angle and booster air flow did not have any identificable effect either. Appendix E shows a trend of SO_2 after furnace where nozzle angle and booster air flow changes are marked.

8.4 Booster air

Booster air was used to improve the penetration of limestone to furnace. Maximum capacity of booster air fan was 9.4 m^3/s. The fan was equipped with a manual VIV to control air flow. During the tests the VIV was fully open unless specified differently. Air flow was measured by Annubar.

The effect of booster air was tested together with limestone nozzle angle (see previous chapter). Those tests indicated insignificant effect on sulphur removal in furnace. To ensure this result, more changes were made to booster air flow. The fan was started or stopped 44 times. The average effect of starting the fan was a 1.3 % decrease in SO_2 level after furnace. As the average effect of stopping the fan was 0.5 % increase in SO_2 level, the conclusion is that booster air improved SO_2 removal in furnace about 1 %. A table of booster air changes is in appendix F.

8.5 Boiler Load

Reducing boiler load caused many changes in furnace conditions favorable to limestone injection. A combined effect of reduced temperature, increased excess air and increased residence time can be seen in figure 7 on furnace SO_2 removal.

There was some indication that SO_2 removal in reactor might increase with reduced load. This could be seen when ash recycle was not used. With recycle there were only few data points at 200 MW load which did not indicate a change in reactor performance with reduced load.

8.6 Reactor outlet temperature approach to dewpoint

Decrease in reactor outlet temperature increases SO_2 capture in reactor. This is due to a closer approach to water dew point and increased water flow to reactor. Both of these improve SO_2 absorption conditions and the collission efficiency between water and calcium containing particles. The main mechanism of SO_2 removal in humidification reactor is understood to be SO_2 absorption to a water film on a particle and a fast ionic reaction in the water film.

The effect of approach temperature on SO_2 removal is shown in figures 16 and 17 for 300 MW with ash recycle. Figures 18 and

19 describe reactor performance at 300 MW without ash recycle to reactor.

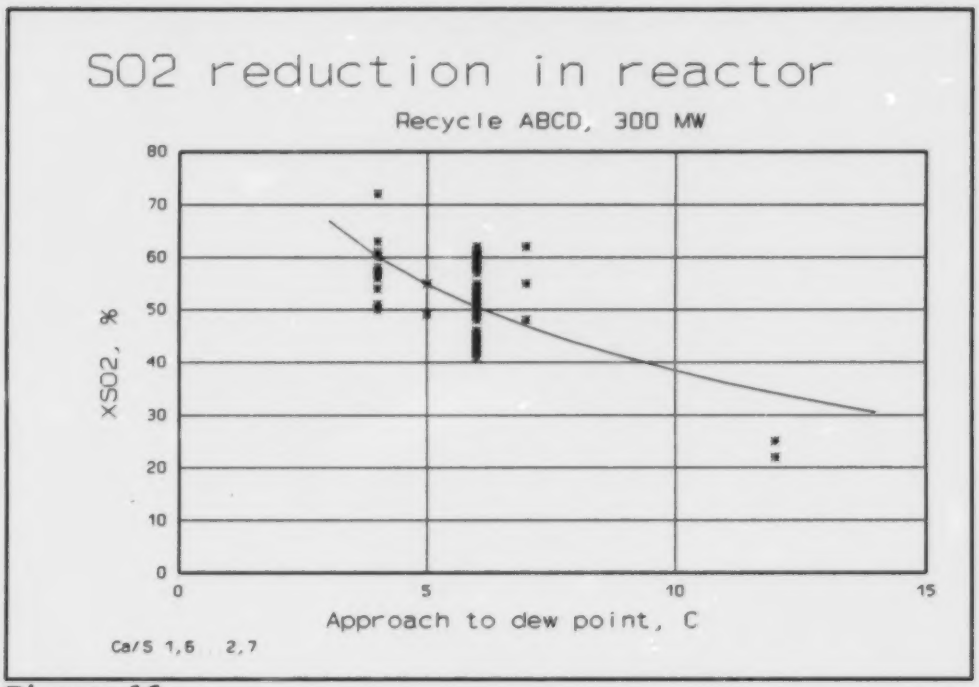


Figure 16

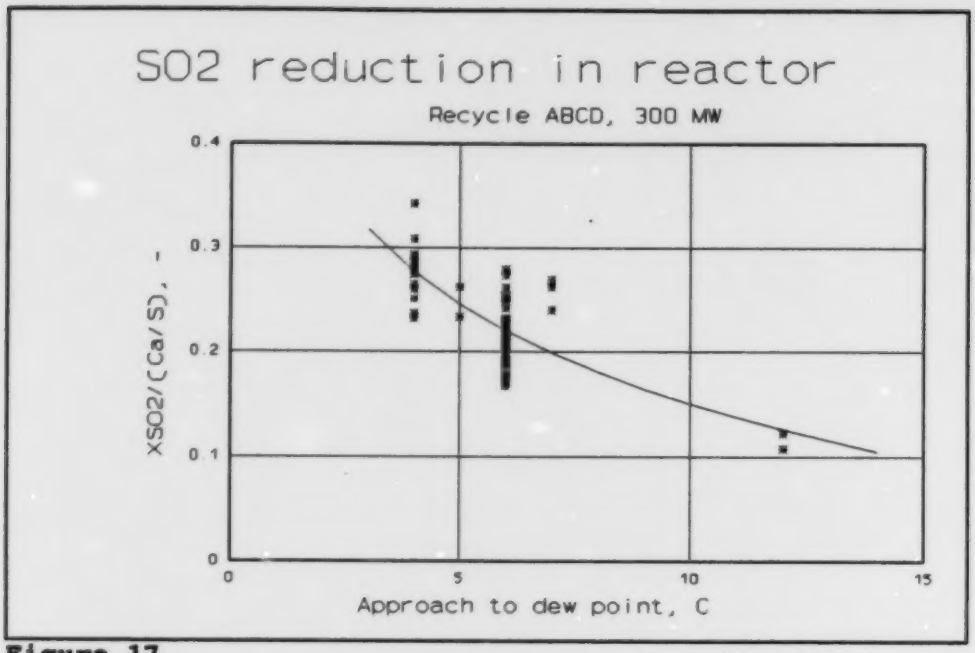


Figure 17

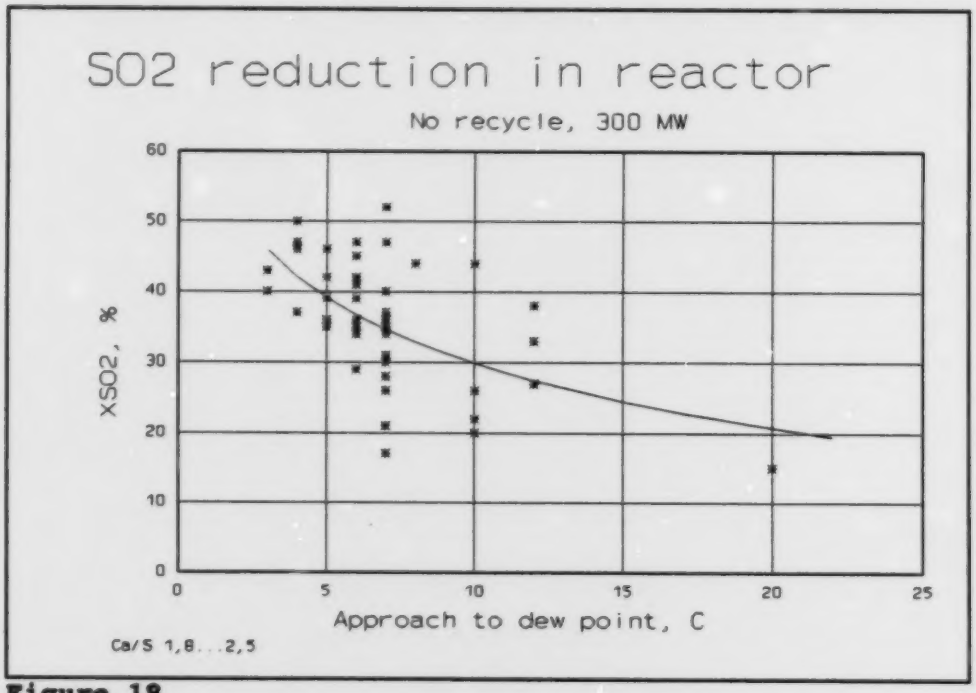


Figure 18

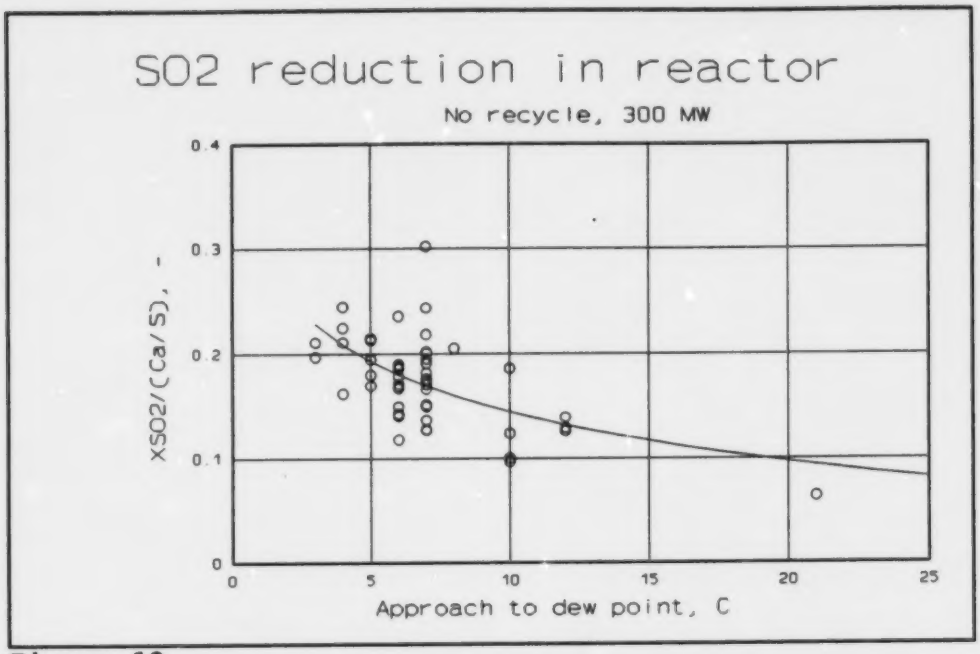


Figure 19

8.7 Recycle of fly ash

At PRPS boiler #1 flue gas is divided to two precipitators and two ID fans. The humidification reactor is installed to the west side duct between air heater and "A" precipitator leaving 50 % of flue gas without humidification.

Fly ash can be recycled to reactor inlet duct before humidification nozzles. Recycle ash can be taken from any of 4 first field hoppers of the two precipitators or from all of them. Hoppers were named from A to D so that A and B hoppers are on west side and C and D on east side (were flue gas is not humidified). Different combinations of precipitator hoppers where ash was recycled from were called AB, CD and ABCD.

An estimated 70 to 80 % of fly ash is collected in first field hoppers of precipitators. Each hopper was equipped with a constant speed rotary feeder feeding ash from the hopper to the recycle line. By comparing regression results for reactor performance with ash recycle from all four hoppers to that without ash recycle it can be concluded that recycle did have a positive effect on SO_2 removal in reactor. As an average at Ca/S ratio 2 and ΔT 4°C the increase in SO_2 removal was 30 %.

The mass flow of recycled material was not measured and may thus have varied during testing. Rotary feeders were not able to feed all material that was collected in first row hoppers to the recycle line.

The effect of ash recycle was alternatively studied by immediate changes in SO_2 removal in reactor when the combination of rotary feeders used for ash recycle was changed. Using this method recycle did increase SO_2 removal in reactor at 300 MW load by an average of 6 % when either hoppers A and B or C and D were used. When all hoppers were used for recycle the increase in SO_2 removal was 28 %. Data extracted from process trends for this study is collected in appendix G.

8.8 Combined furnace and reactor performance

Figures 20 to 23 in this chapter describe the total SO_2 removal in LIFAC® process. For furnace and reactor performance the regression results were used to obtain the total performance.

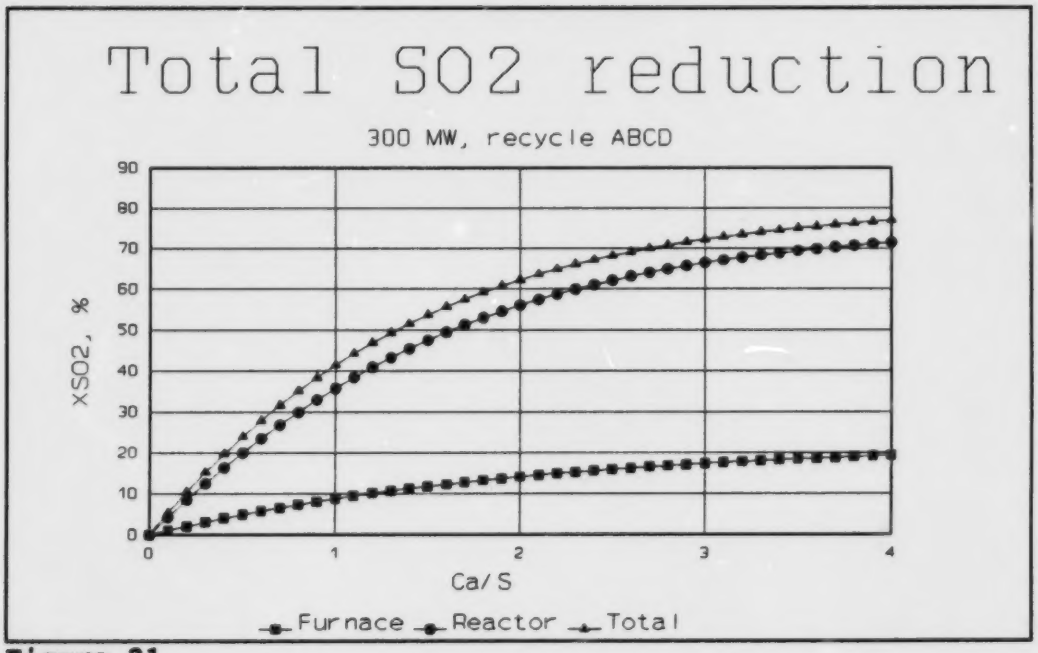


Figure 21

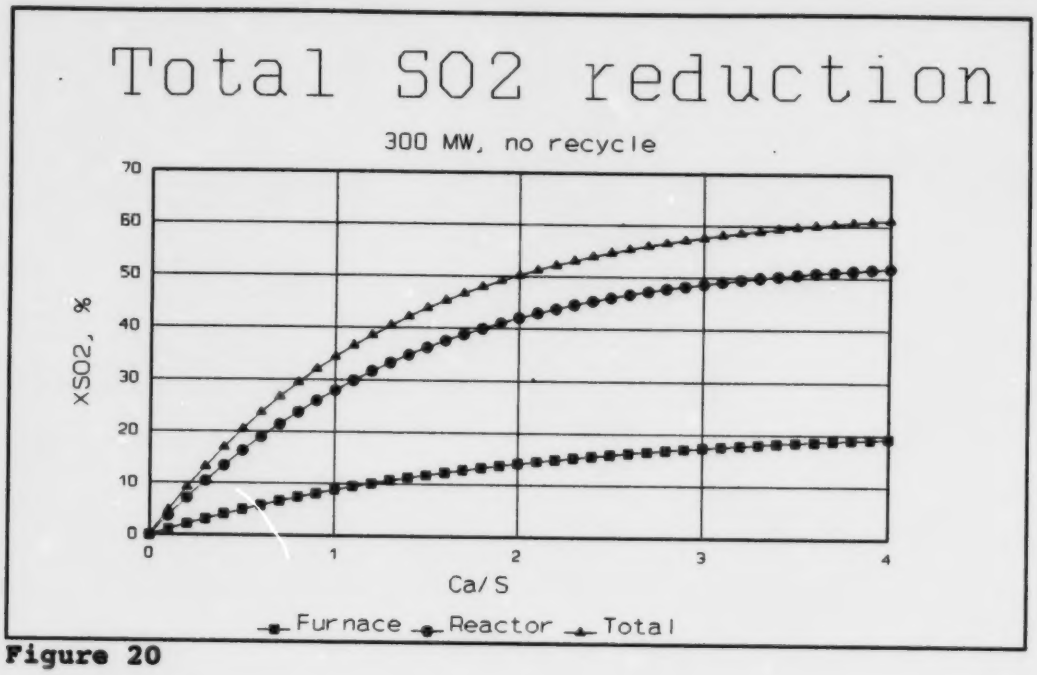


Figure 20

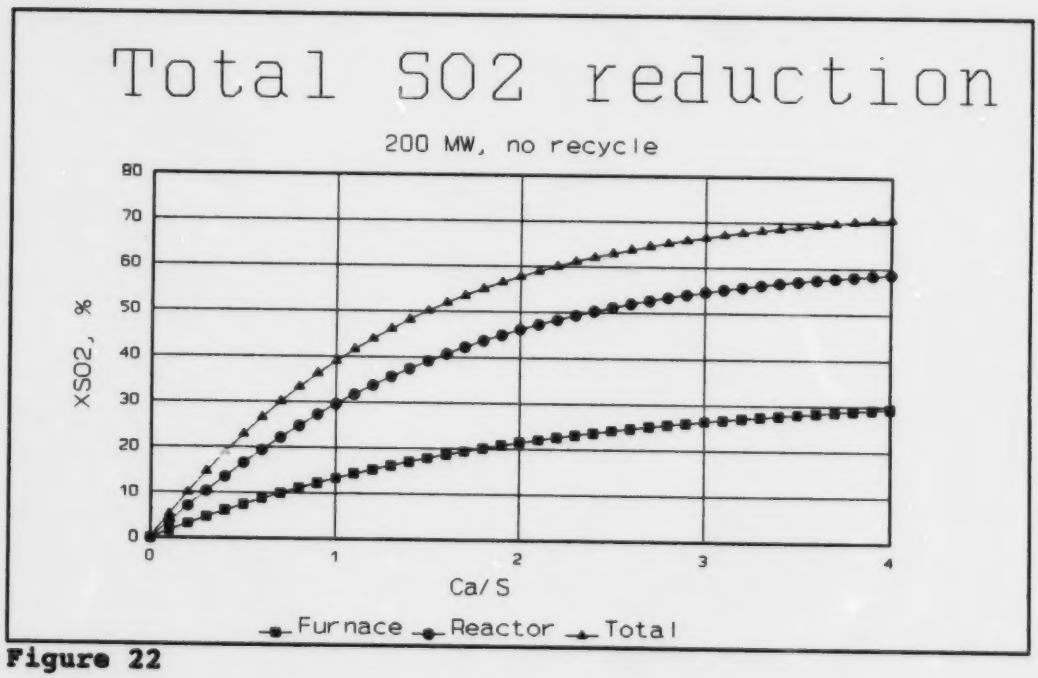


Figure 22

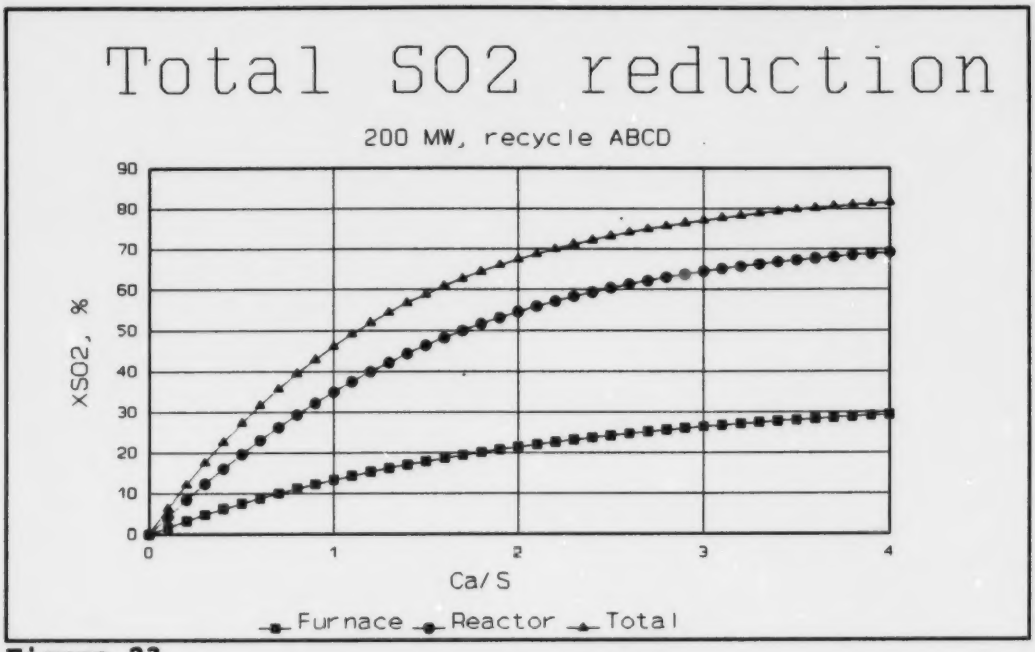


Figure 23

10 OPERABILITY

The operability of the process is designed to be addressed in detail in phase II testing, but the following observations were made during parametric testing:

Reactor cleanliness

After 80 hours of operation at ΔT 6°C the reactor was found to be clean. After 70 hours of operation at ΔT 4°C the reactor was still found clean. Ash recycle did not cause buildup in reactor.

Opacity

LIFAC® testing was seen to have a negative effect on stack gas opacity. The exact influence of LIFAC® has not yet been determined. Precipitator performance will be measured in phase II.

Plant ash system scaling

The scaling index in ash water did increase during testing. The index is mostly affected by the amount of $CaSO_4$ which was increase because of limestone injection.

11 CONCLUSIONS

The most important variables on SO_2 removal were found to be injected Ca/S ratio, humidification reactor outlet temperature approach to dew point (ΔT), ash recycle to reactor and boiler load. The combined effect of furnace temperature and excess air was found to be significant, but the effects of each variable could not be separated. Booster air and limestone injection nozzle angle did not effect SO_2 removal.

The optimum process conditions at a fixed Ca/S ratio were found to be reduced load, minimum approach to dew point and ash recycle from all four hoppers.

Figures 19 and 21 describe the total SO_2 removal achieved in LIFAC® process. At 300 MW load, Ca/S ratio 2 and ΔT 4°C the total SO_2 removal achieved was 63 % with ash recycle to reactor from all four hoppers. At 200 MW load the total removal was 68 %.

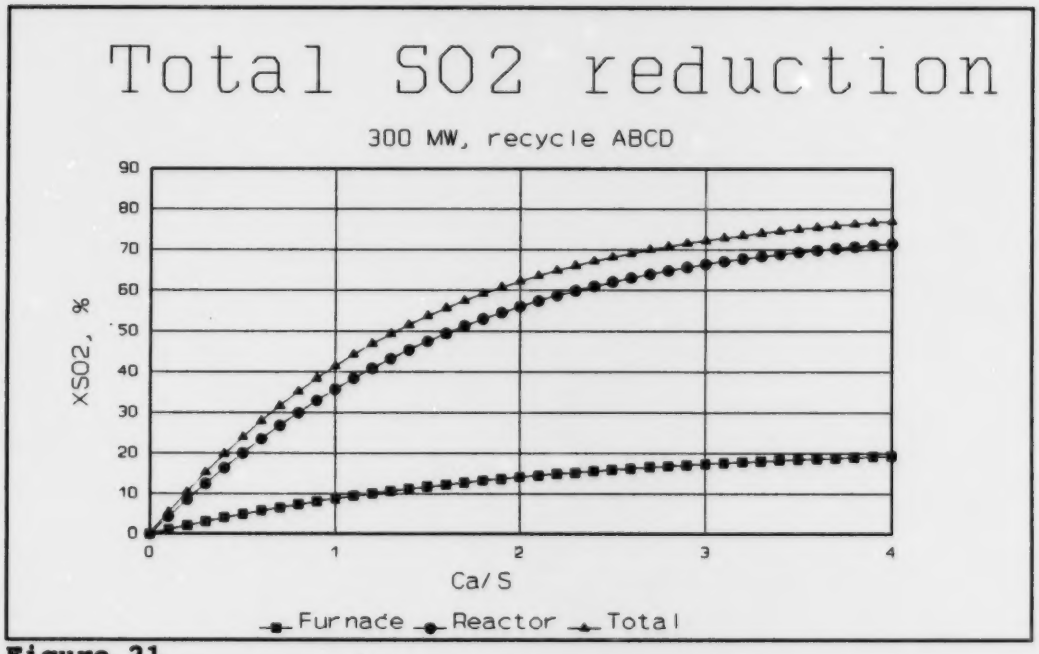


Figure 21

After a 70 hour operability test at 300 MW load and ΔT 4°C the reactor was found to be clean.

The effects of continuous operation of desulphurization on plant operations and auxiliaries will be addressed in phase II testing, where the process will be operated for two months.

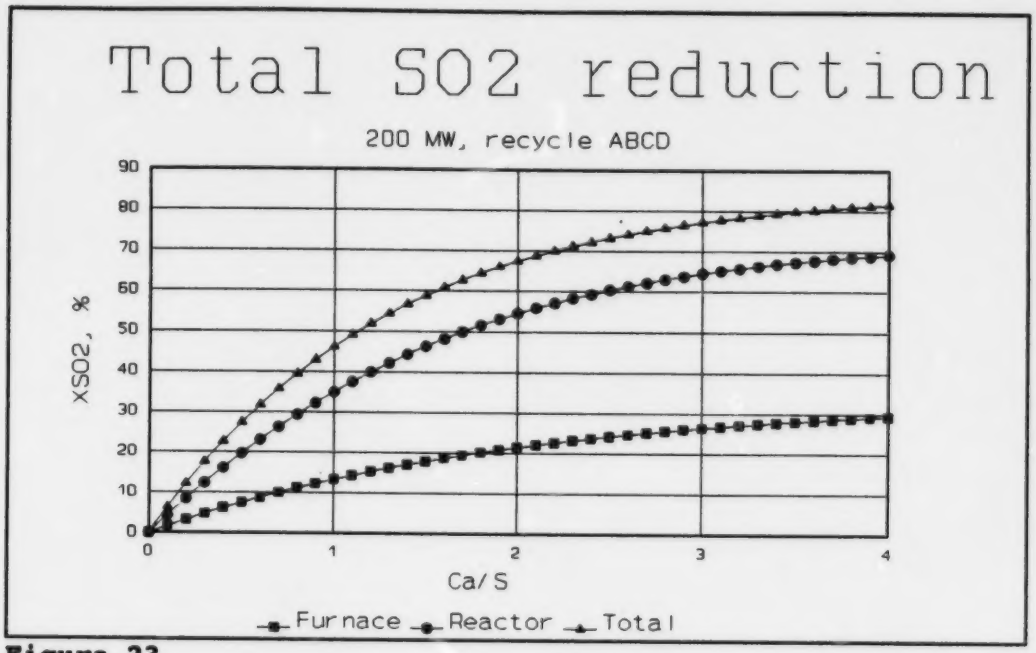

Total SO2 reduction
200 MW, recycle ABCD
XSO2, %
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
Ca/S
Furnace
Reactor
Total

Figure 23

12 APPENDIX LIST

A	Sorbent injection design for Poplar River Unit #1
B	Limestone analysis results
C	Coal analysis results
D	Test data table
E	Injection angle changes, process trend
F	Booster air changes, table
G	Recycle changes, table
H	Boiler efficiency report
I	Study of limestone injection/comparison of Canadian limestone types

APPENDIX A

SORBENT INJECTION DESIGN FOR POPLAR RIVER UNIT #1

Summary of Design Results

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January 4, 1990

1.0 OBJECTIVE

The Sask Power of Canada and the Tampella Ltd. of Finland are currently considering installation of a demonstration LIFAC system for SO_2 emissions control on unit #1 of the Poplar River Power Station. As part of the program, EERC has conducted a process design study for the limestone injection portion of the LIFAC system. The objective of the process design study was to use a generalized and validated methodology to determine the boiler specific sorbent injection parameters for optimum in-furnace SO_2 removal, and to evaluate the impact of sorbent injection on boiler thermal performance for various operating conditions and design parameters. Of particular interest of the design study was specification of injection parameters for nominal full load operation, since the boiler has been operated mostly under full load conditions.

2.0 APPROACH

The approach to sorbent injection design involves three main elements: boiler heat transfer modeling, sorbent injection system design, and isothermal physical flow modeling. Each of the main elements is an integral part of the whole design process, and Figure 2-1 shows an overall procedure toward final design specifications.

In the first instance a heat transfer model is set up for the host boiler design and operating conditions, and for the boiler under a range of velevant boiler loads. The results of the heat transfer modeling are used to identify elevations in the boiler which are expected to be favorable for sorbent injection. As the second design element, a reduced scale plexiglass model is then constructed to permit evaluation of the flow field and injection characteristics. The approach to the final element, which is the sorbent injector design, is relatively empirical. In this process, injector characteristics are tailored to the boiler's specific flow field and injection elevations by evaluating injection parameters such as nozzle size, injection velocity, and jet numbers, etc. This information is then translated back to full scale system to specify design parameters.

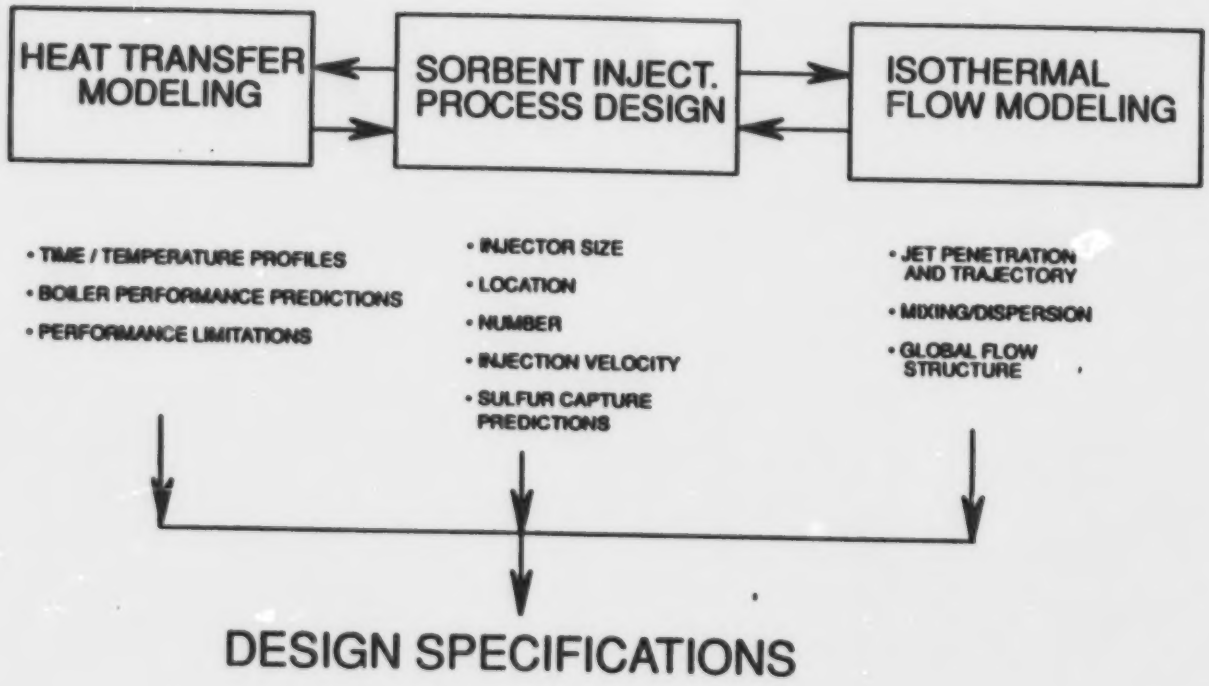

Figure 2-1. Approach for sorbent injection design.

For final design evaluation, the sorbent injection parameters are incorporated back into the heat transfer model to allow recalculation of the temperature field and prediction of the impact on boiler performance. Sulfation model is then applied to predict SO_2 capture based on known sorbent properties. Usually sorbent reactivity data is derived from small bench scale testson specific sorbents, or can be taken from an available experimental data base.

3.0 HOST BOILER

The boiler is a 300 MW_e natural circulation, balanced draft, single reheat, tangetially fired unit designed by CE Canada. Figure 3-1 shows general arrangement of the boiler. The MCR for the unit is rated at 246 kg/sec of superheated steam at 1005 ^{o}F and 1885 psig, and the reheat steam is rated at 222 kg/sec at 1005 ^{o}F and 435 psig. Furnace gross heat release rates for the boiler are rated at 199 Kw/M^2 (per EPRS) and 110 Kw/M^3 (per volume), respectively. The boiler furnace is 42 ft in depth, and 53.5 ft in width.

The boiler uses lignite coal as fuel, which has approximately 35 % to 40 % moisture. At MCR condition, 65.4 kg/sec of the lignite coal is fired through 20 burners at five elevations. Primary air is supplied by two primary air fans and is preheated by a Ljungstrom primary air heater (P.A.H). Leakage for the P.A.H. is around 17 %. Secondary air is supplied by two forced draft fans and preheated by another Ljungstrom air heater (S.A.H). Leakage for the S.A.H. is about 5.5 %. Two induced draft fans transport the flue gas through the superheater and reheater tube banks in the front pass, an economizer in the backpass, then through the two air heaters ,an ESP, and finally discharged to the stack. Flue gas for the P.A.H bypasses the economizer.

Based on the boiler design data, the calculated heat transfer surface areas of the tube banks are: 1093 M^2 for the platen superheater, 2468 M^2 for the finishing superheater, 3022 M^2 for the reheater, 4785 M^2 for the primary superheater, and 9764 M^2 for the economizer. Flue gas velocity leaving furnace is designed at 13.7 m/sec, and the design velocity entering superheater is 14.4 m/sec.

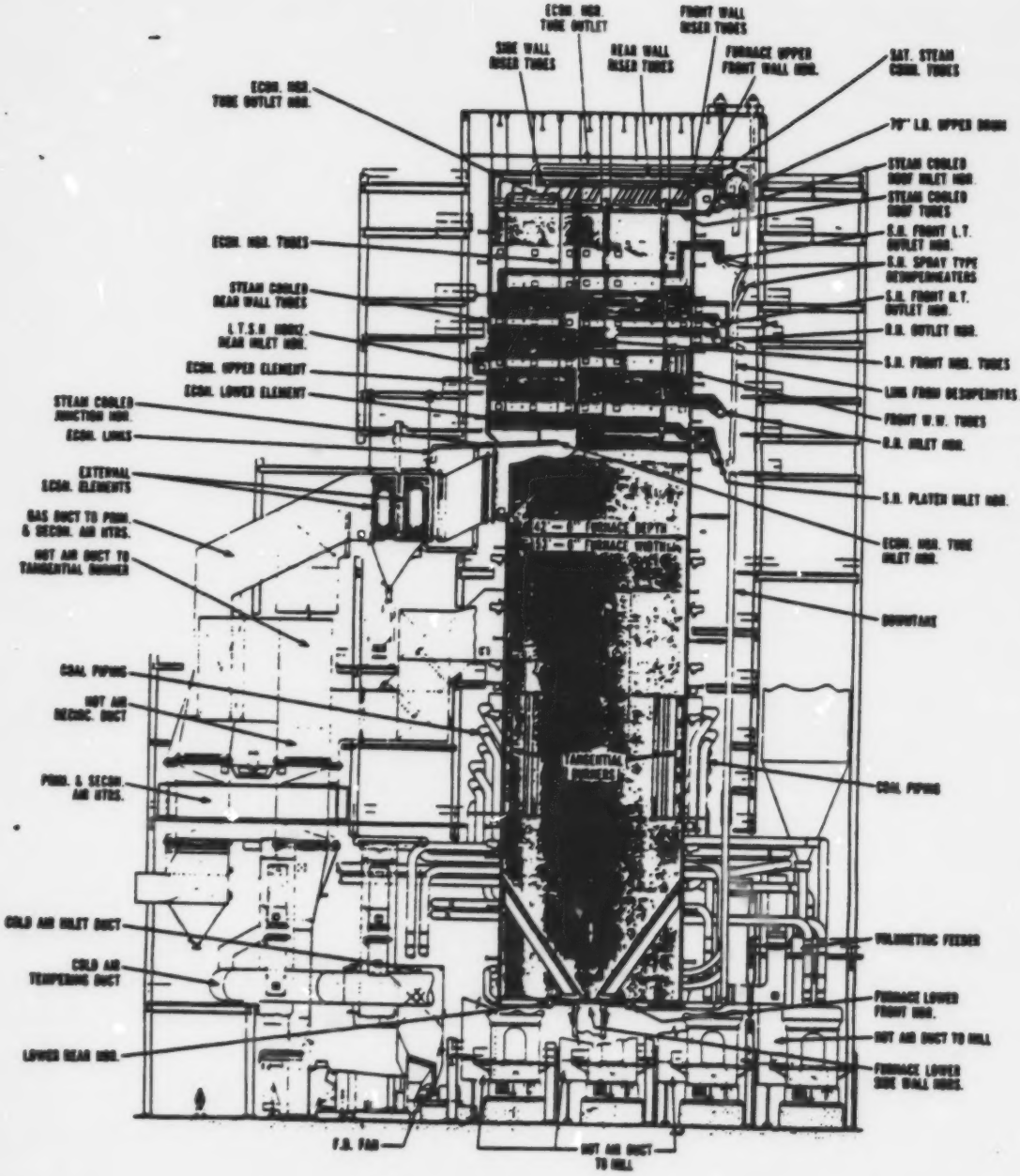

Figure 3-1. Poplar River Unit No. 1 general arrangement.

4.0 BOILER PERFORMANCE MODELING

The thermal behavior of Poplar River Unit 1 has been studied to examine the effect of Sorbent Injection (SI) on its performance. Parameters which have been varied include boiler load, fouling, burner tilt, and the elevation for sorbent injection.

The thermal model of Poplar River is built around a two dimensional heat transfer code of the furnace region, in which radiative heat transfer is predominant. This code is described in the following section. The results of this code may be used to provide essential data for further predictions, including overall boiler performance and sulfur capture.

4.1 Heat Transfer Modeling

Thermal performance in the furnace and radiative heat exchanger section is predicted using a two dimensional steady state heat transfer model (referred to hereafter as the "2D code"). In this code an axisymmetric cylindrical grid is used to represent the furnace. The grid is divided axially and radially into zones, providing for spatial resolution of heat transfer quantities.

The heart of the computational technique is the radiation model. The model uses a semistochastic approach to track radiative beams proceeding through processes of emission, gas-phase attenuation, surface absorption and reflection, until all energy in each beam is absorbed (within a prescribed numerical tolerance). Convective heat transfer is also calculated. Heat transfer surfaces include water walls and distributed heat exchangers.

The flow field is not calculated but is prescribed as an input. The prescription allows for specification of velocity profiles, recirculation patterns, and turbulent exchange between zones. In practice, specified flow fields are generally based on isothermal flow observations, and on experience in modeling similar boilers. For the cases presented here, the effect of burner tilt is modeled by appropriate specification of the flow field.

Combustion is modeled by allowing reactants (char particles, and packets of coal volatiles or natural gas) to move randomly, with probabilities weighted by the turbulent flow vectors. Char particles react according to an Arrhenius rate law. Volatile packets are assigned statistically distributed lifetimes, and each packet reacts completely at the end of its assigned lifetime.

In the study of Poplar River, the region to which this code has been applied runs from the bottom of the hopper to the top of the front pass. This is the region in which radiative heat transfer is judged to be significant. The 2D representation of this region has been divided into 20 horizontal layers, following the direction of flow from bottom to top. This grid is also divided into 5 radial layers.

The length and radius of each major section of the grid are chosen to approximately match both the volume and wall surface area of the corresponding section of the full-scale unit. The dimensions necessary to match volume and surface area result in a grid which is taller and narrower than the actual boiler. However, it is considered most important to match volume and surface area between the model and the actual boiler, to maintain heat transfer similarity. In this report, figures showing axial temperature profiles are presented in terms of actual boiler elevations from the hopper bottom.

Baseline Results

Figures 4-1 and 4-2 show mean gas temperature profiles and surface temperature profiles for baseline conditions at 100% load. Three sets of predictions are included. In Figure 4-1, available design and test data for gas temperatures are also presented.

The three predicted profiles correspond to three different fouling patterns in the boiler. The 2D code does not predict fouling; it must be input based on observation and experience. By comparison with test data, it is judged that current boiler operation is best represented by the case represented by the solid curve, corresponding to fouling which is intermediate to that used in the other two cases. Observation of the peak surface temperature in Figure 4-2 supports this conclusion: the intermediate fouling case does not exceed the expected ash

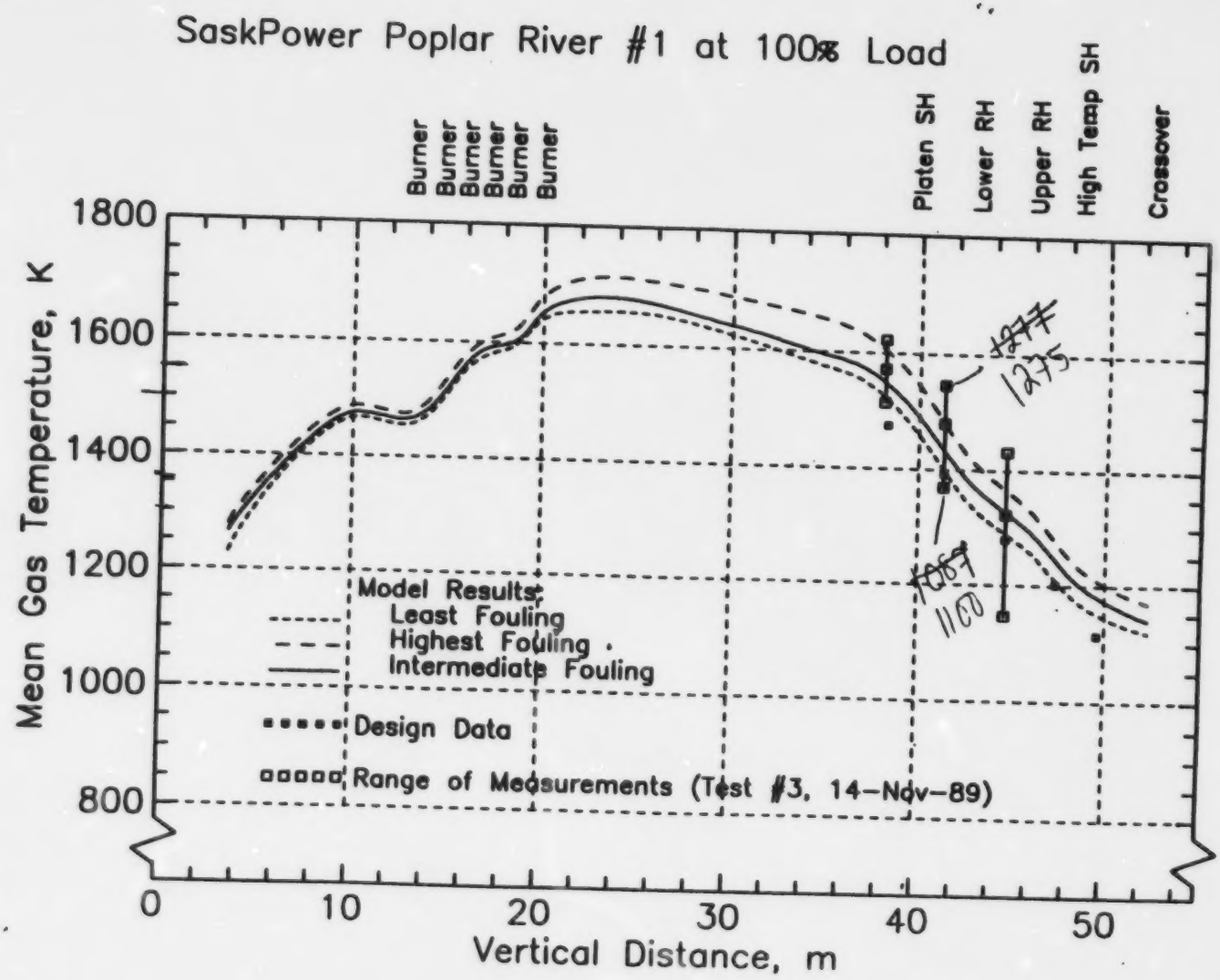

Figure 4-1. Baseline Gas Temperatures at 100% Load.

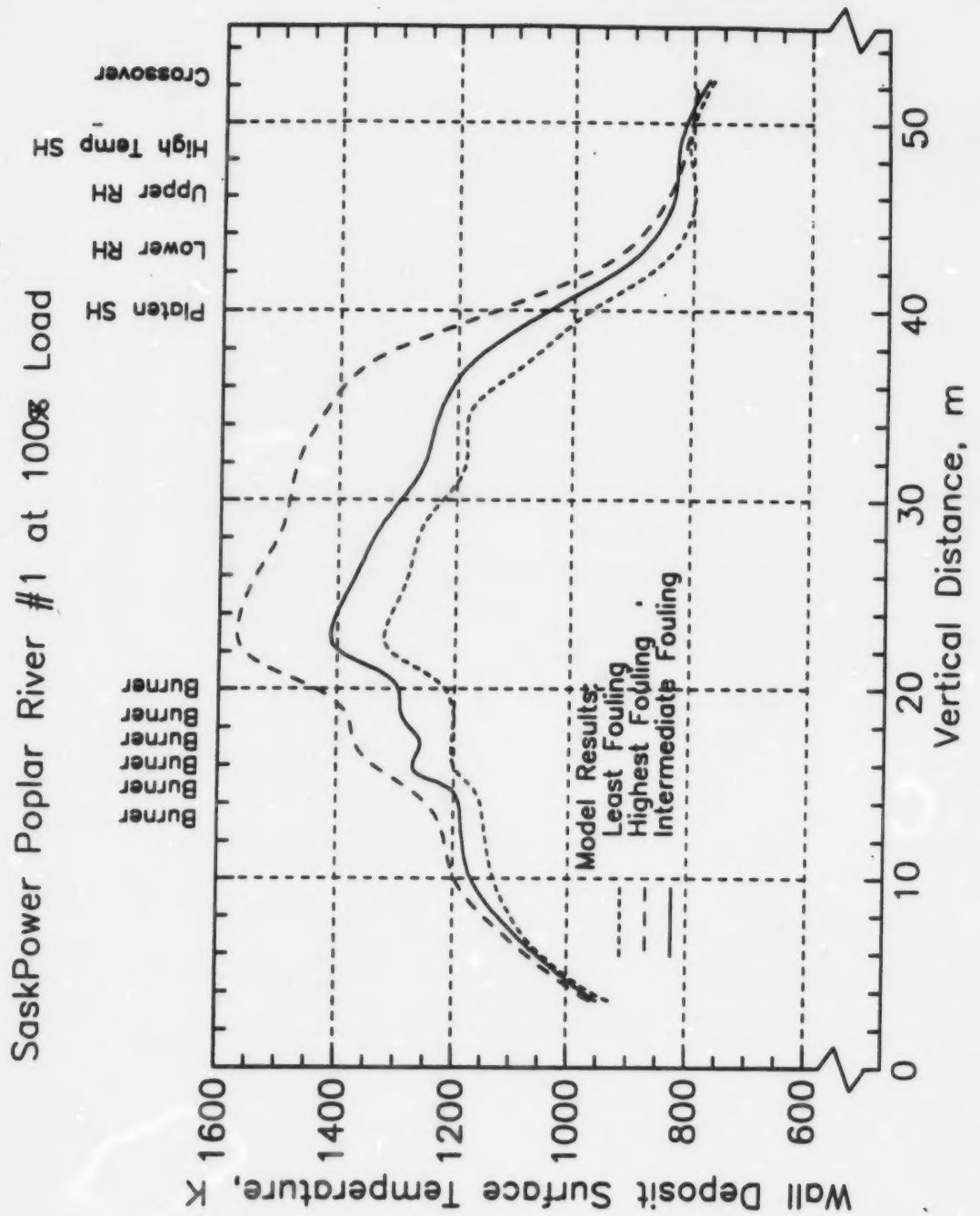

Figure 4-2. Baseline Wall Deposit Surface Temperatures at 100% Load.

deformation temperature. This is consistent with the observed lack of wet slagging in the furnace.

Figures 4-3 and 4-4 show similar figures for 75% load conditions. The fouling patterns used in the predicted profiles are the same as those in the corresponding 100% load cases. These results are compared to available data, relying primarily on design data due to the limited number of test data. It is again judged that the "intermediate fouling" case best represents boiler behavior.

Figures 4-5 and 4-6 show the corresponding figures for 50% load conditions. In the 100% and 75% load cases, the flow field used was based on a downward burner tilt. In this case, it is expected that a reduced tilt would be used to improve boiler performance. The cases shown represent variation in both burner tilt and in fouling. The case with "no tilt, intermediate fouling" is judged to best match the design data at this load.

Sorbent Injection Results

Figures 4-7 through 4-12 compare the selected baseline predictions with corresponding cases in which sorbent injection has been introduced. The injection elevations are as indicated in the figure legend. The transport air flow rate in these cases is 3%, 5%, and 4% of the total burner air, for injection at elevations 800790, 804334, and 807547, respectively. A Ca/S ratio of 2 is used in all cases shown here.

The primary temperature effect of sorbent injection is a reduction in gas temperature at the point of injection, due to dilution by the low-temperature carrier air. The effect on surface temperatures is relatively minor.

The temperature profiles shown here are used in sulfur capture predictions described later (see Section 6.4).

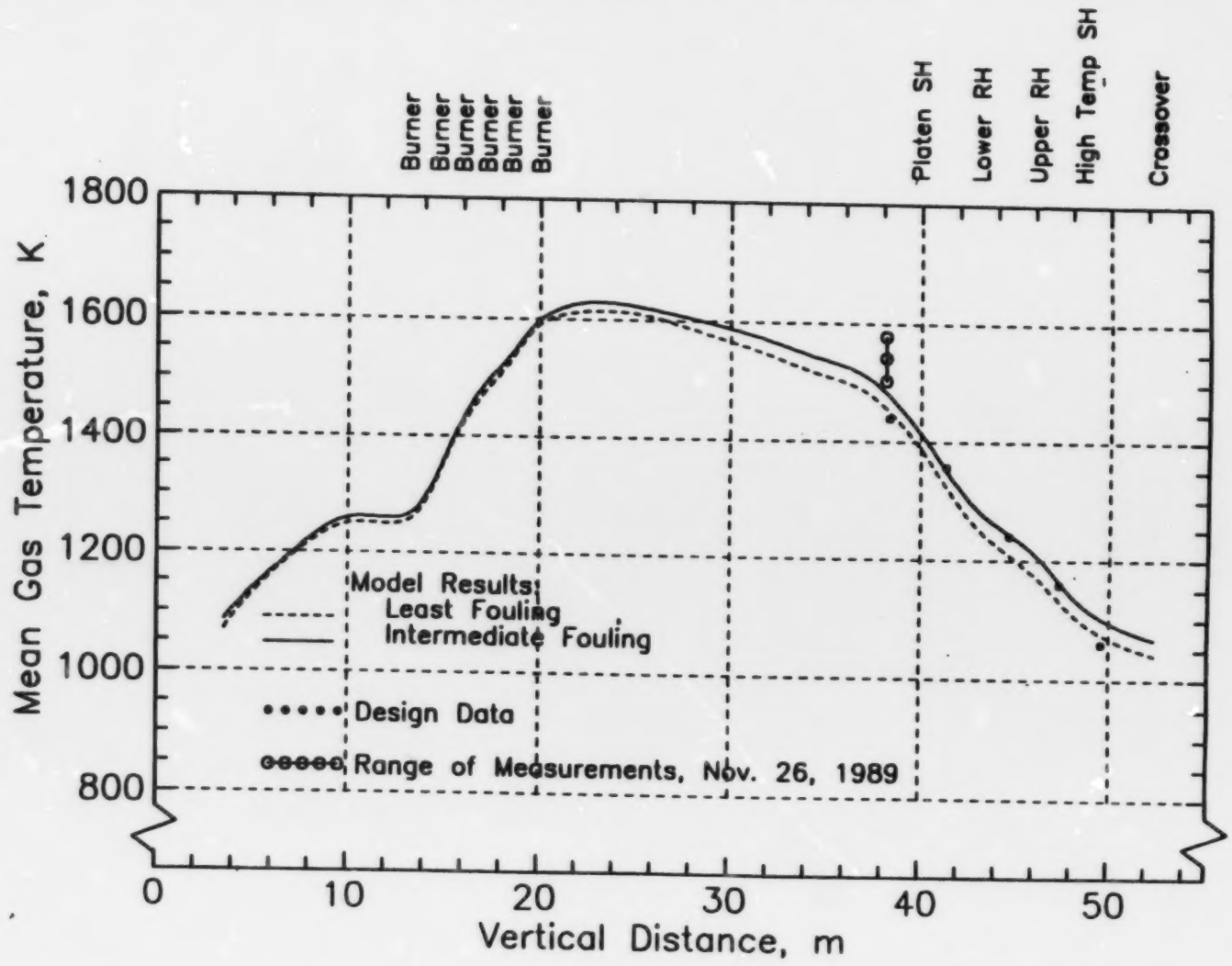

Figure 4-3. Baseline Gas Temperatures at 75% Load.

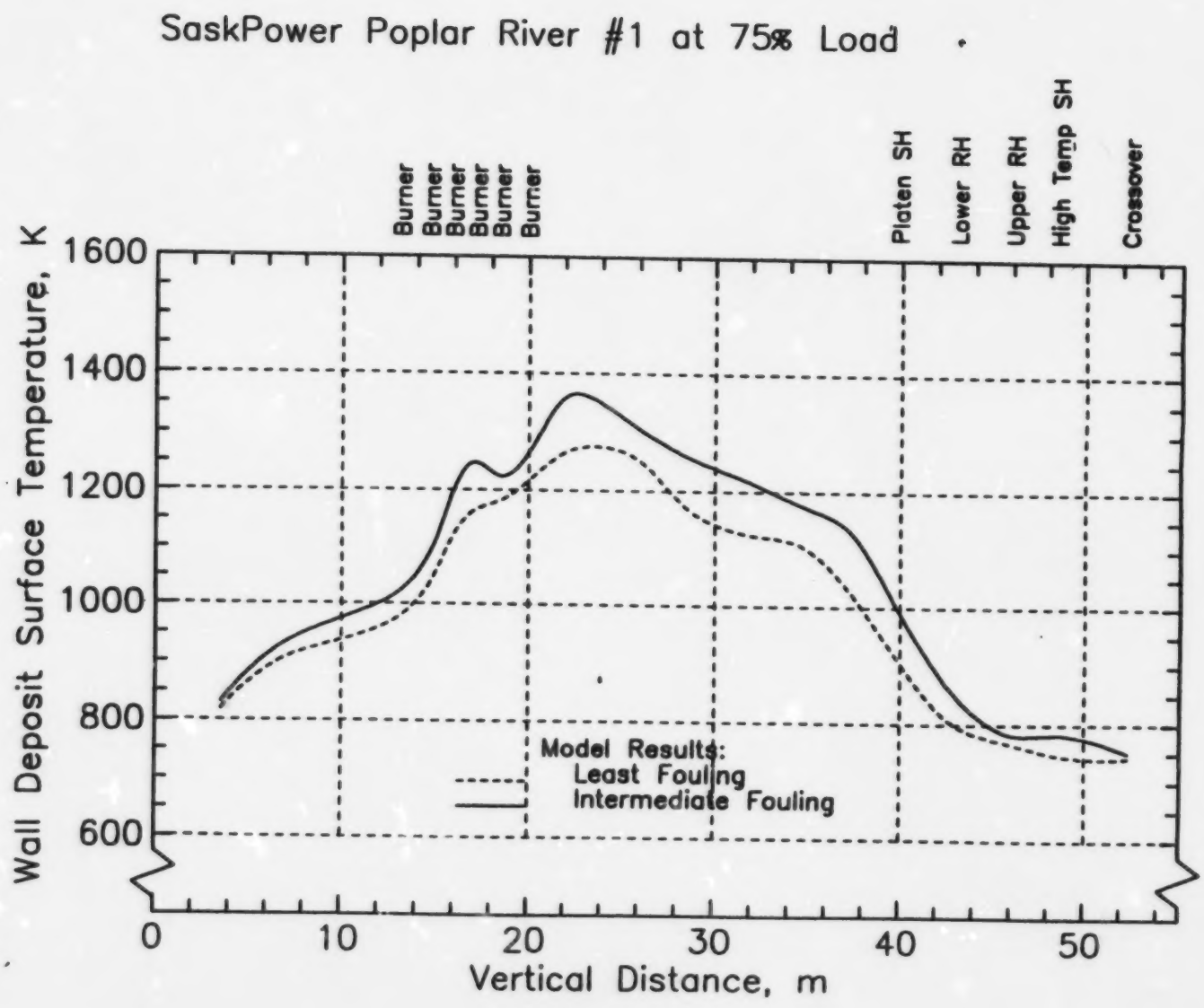

Figure 4-4. Baseline Wall Deposit Surface Temperatures at 75% Load.

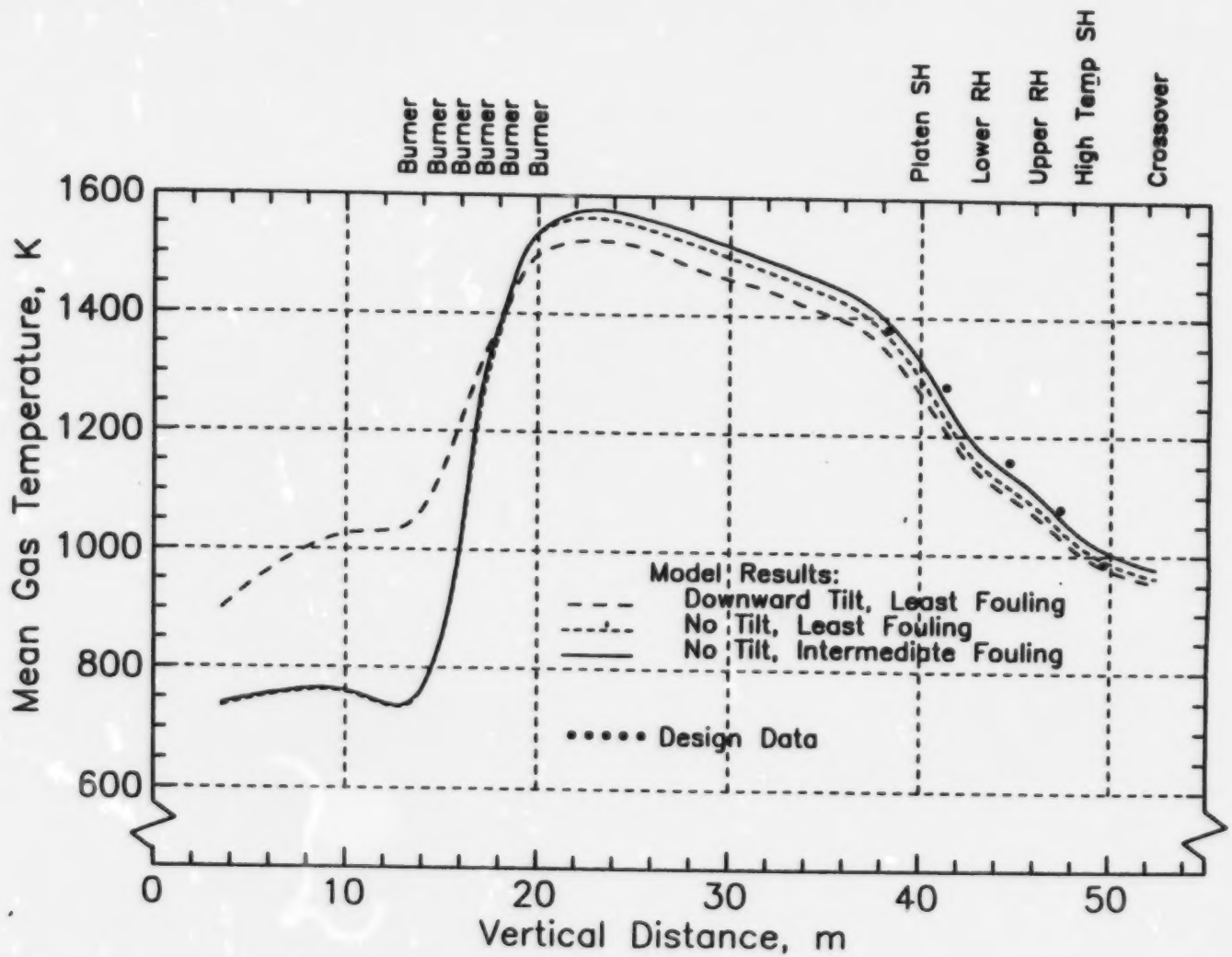

Figure 4-5. Baseline Gas Temperatures at 50% Load.

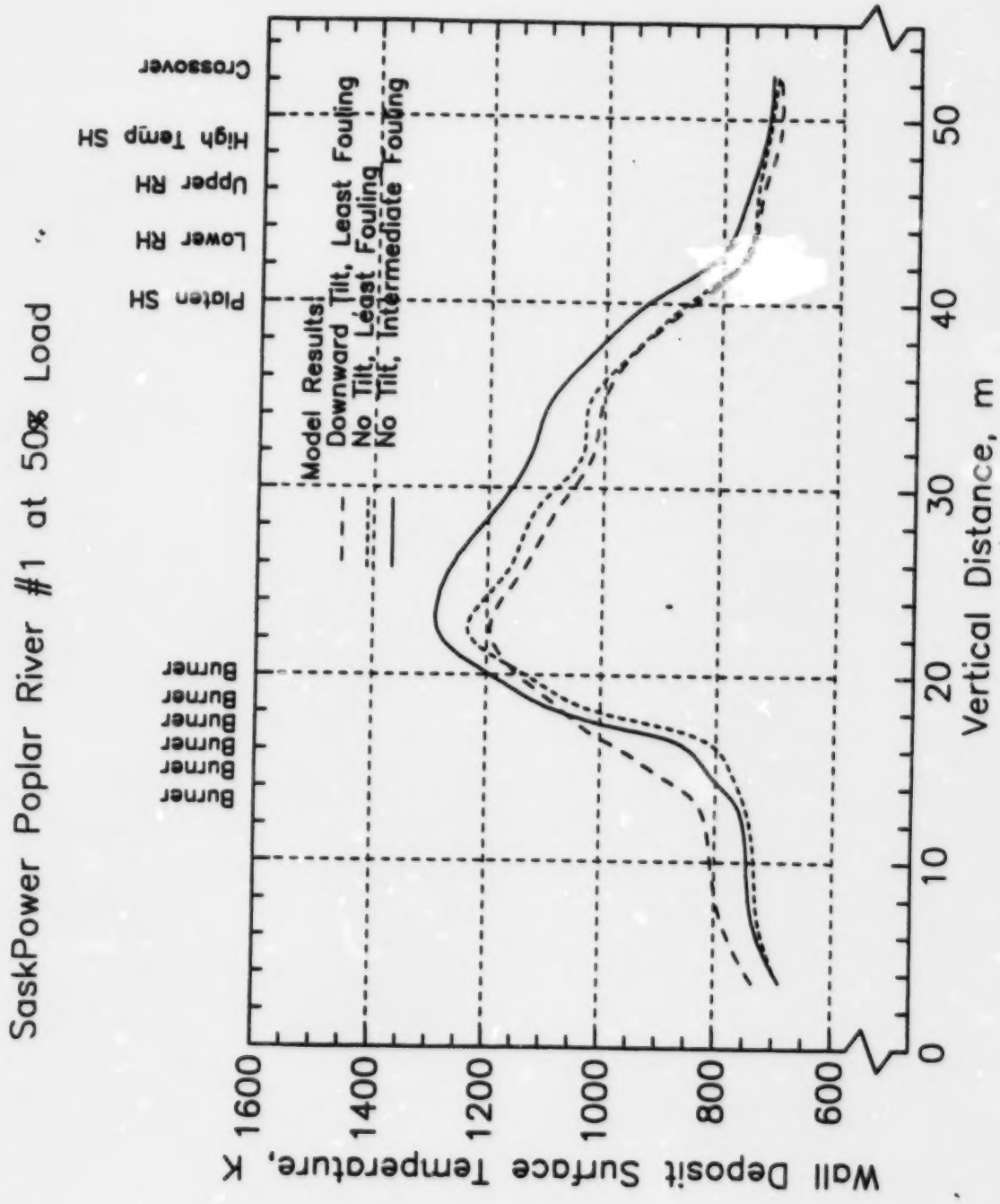

Figure 4-6. Baseline Wall Deposit Surface Temperatures at 50% Load.

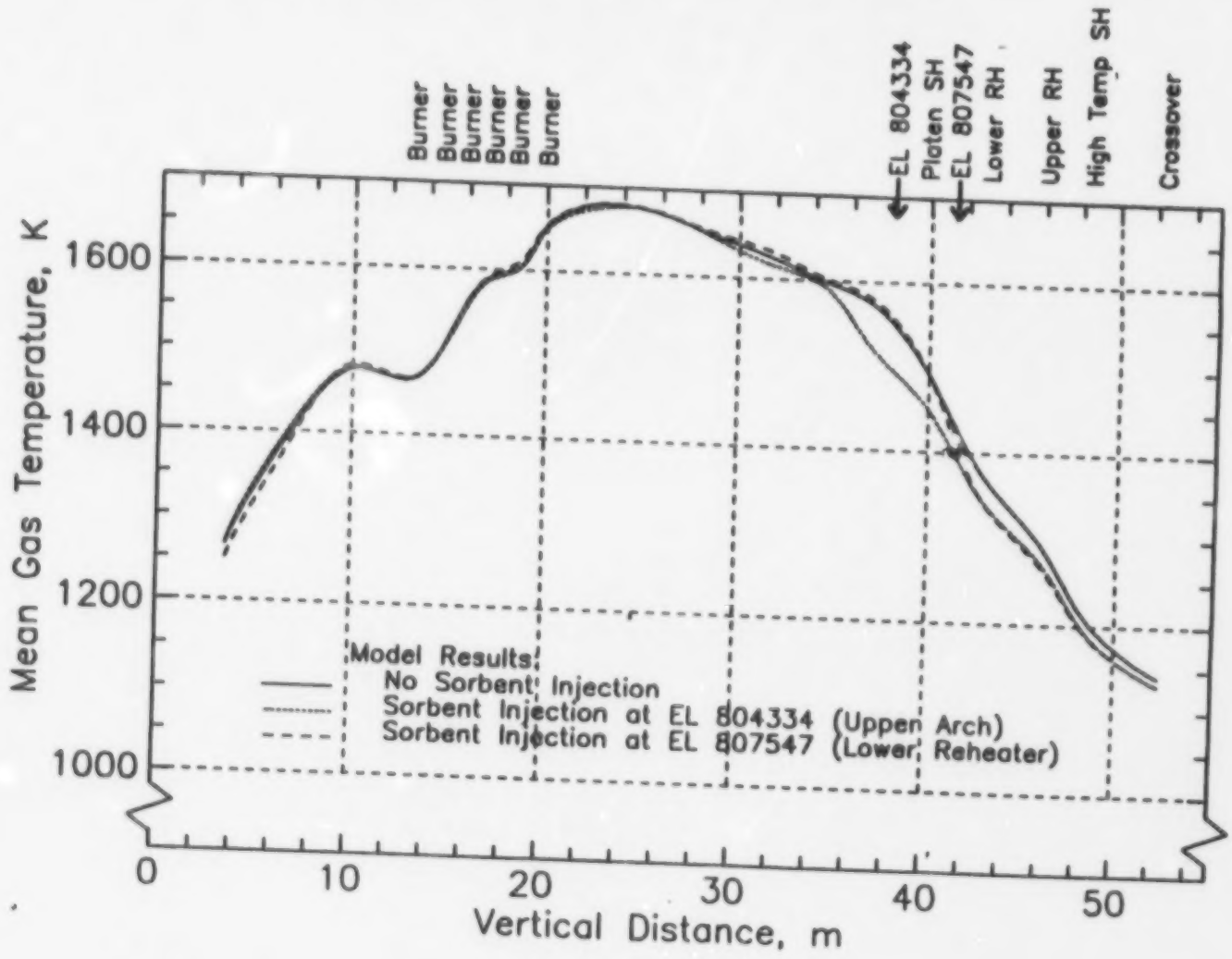

Figure 4-7. Gas Temperatures at 100% Load: Effect of Sorbent Injection

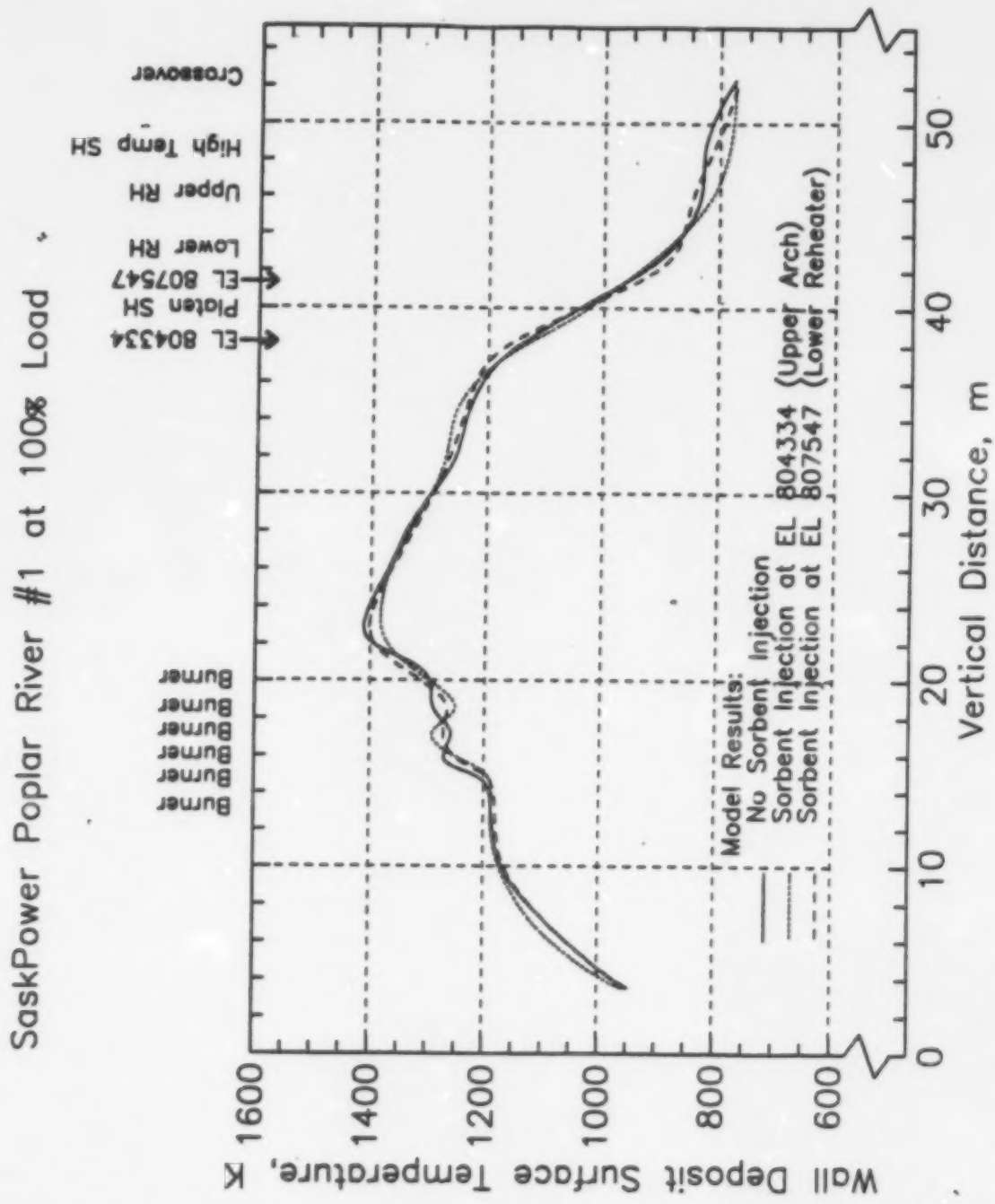

Figure 4-8. Wall Deposit Surface Temperatures at 100% Load: Effect of Sorbent Injection

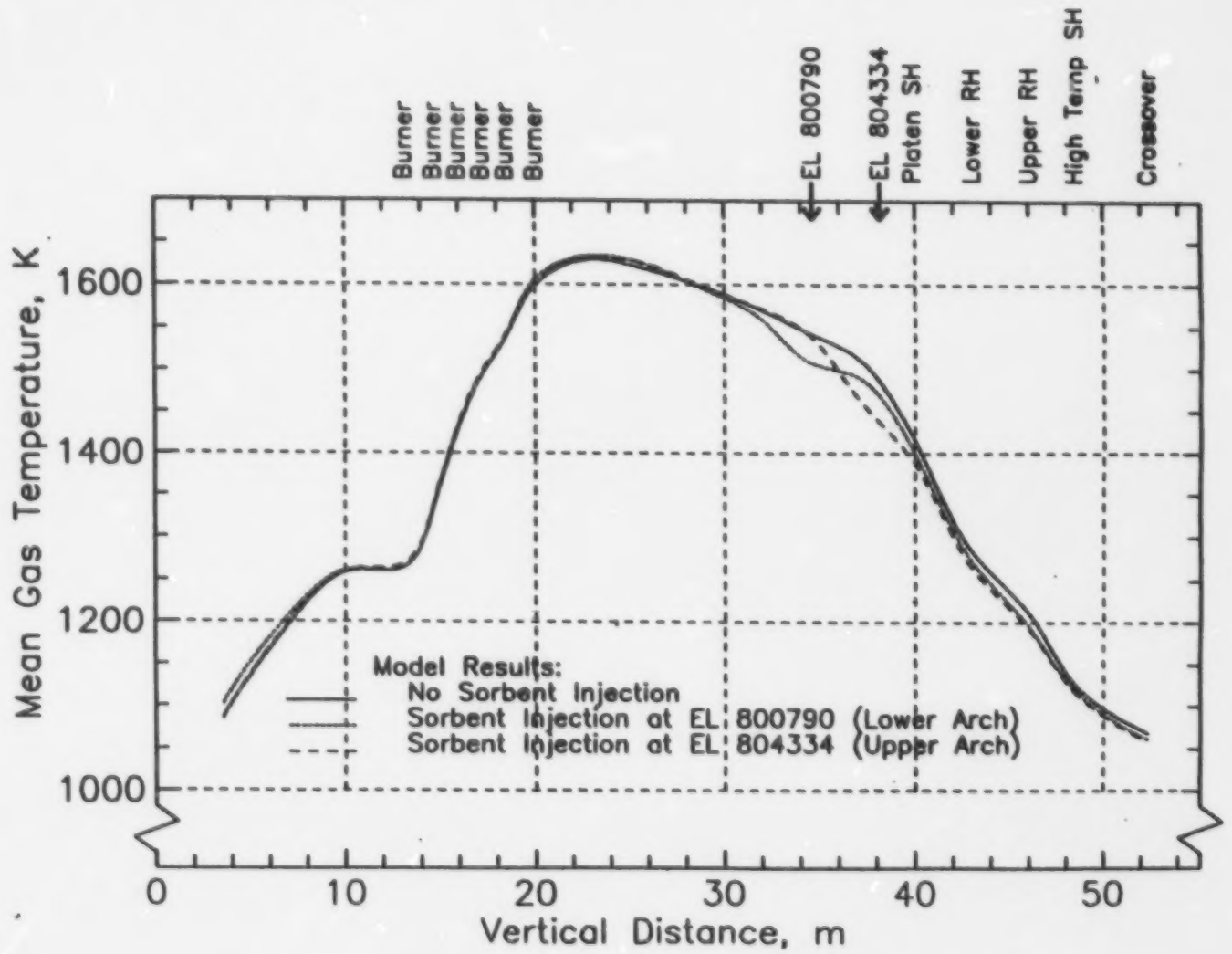

Figure 4-9. Gas Temperatures at 75% Load: Effect of Sorbent Injection

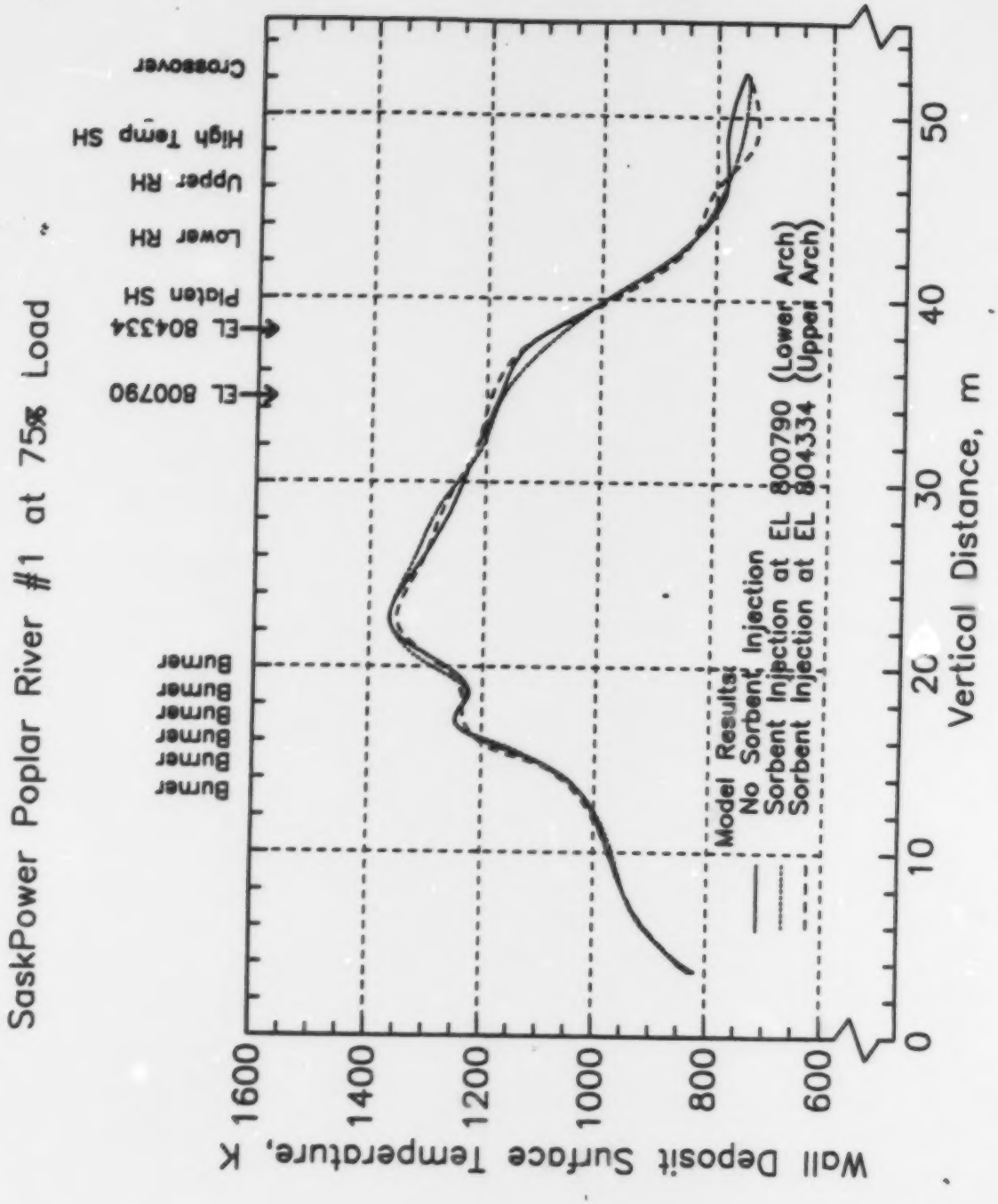

Figure 4-10. Wall Deposit Surface Temperatures at 75% Load: Effect of Sorbent Injection

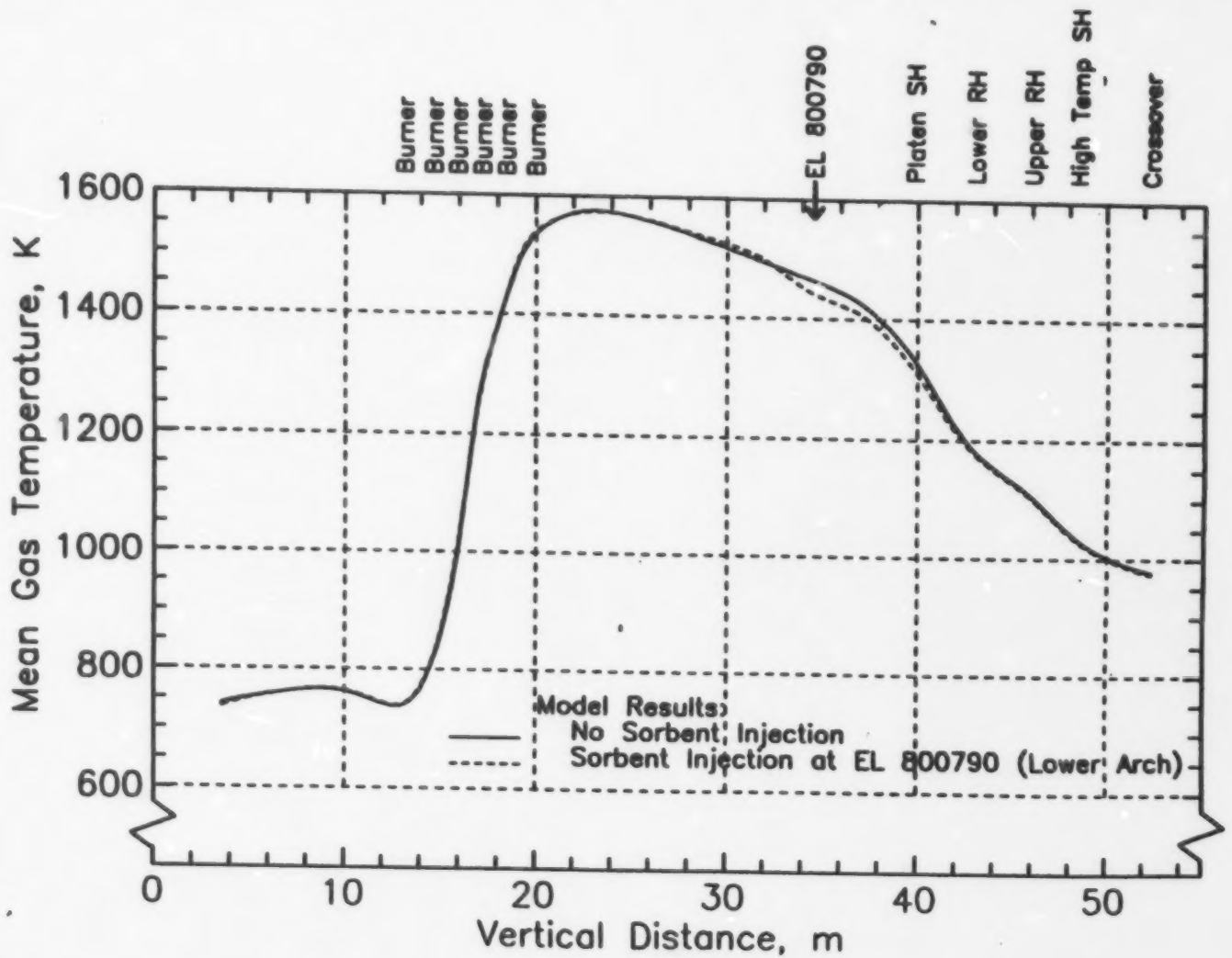

Figure 4-11. Gas Temperatures at 50% Load: Effect of Sorbent Injection

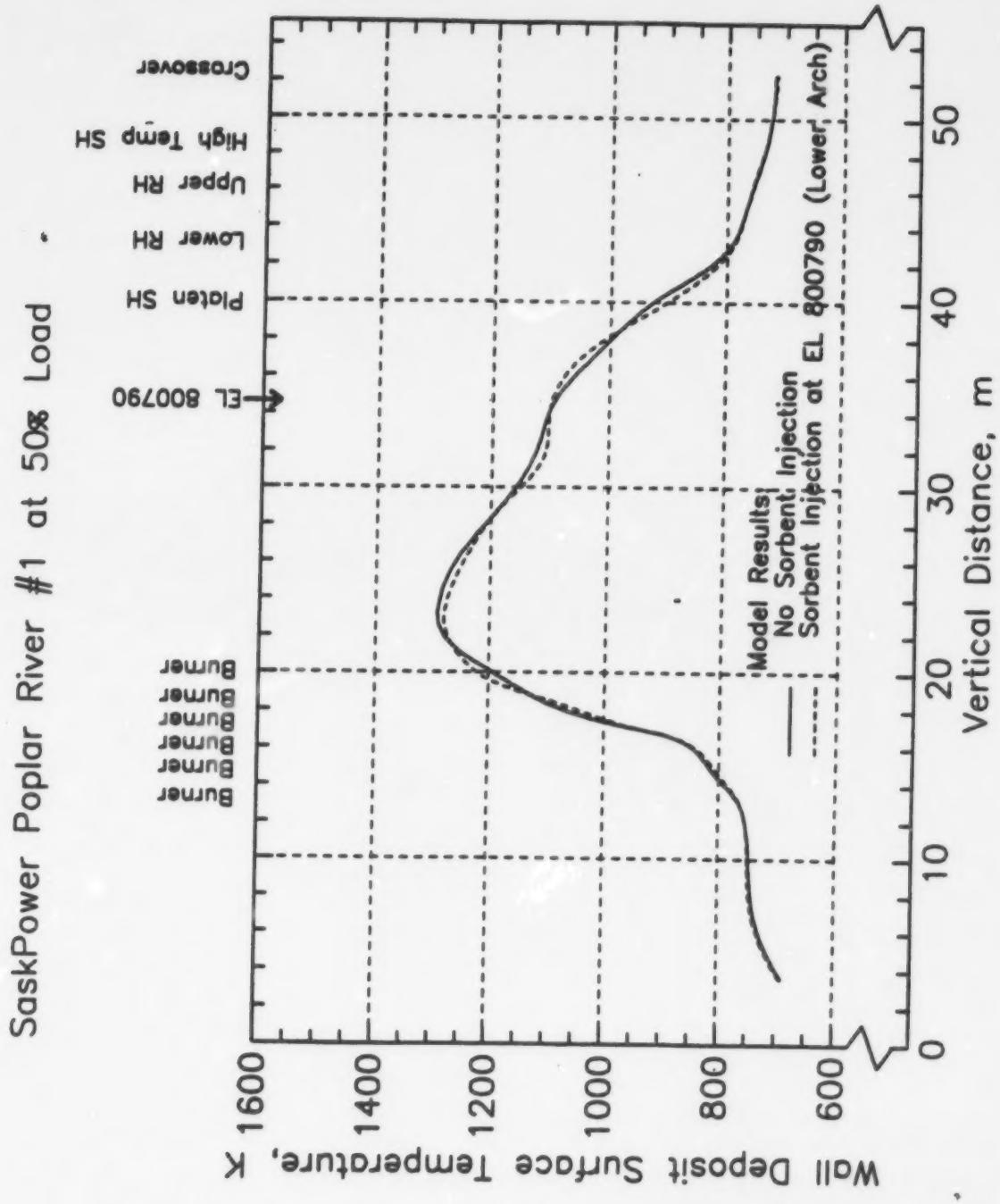

Figure 4-12. Wall Deposit Surface Temperatures at 50% Load: Effect of Sorbent Injection

5.0 ISOTHERMAL FLOW MODELING

Furnace flow field is an important determinant for sorbent injection process design. Information on global flow structure within the boiler furnace is one critical parameter required to determine optimum sorbent injection configurations. Normally, the required level of details in boiler flow field information is not available from the plant. One method to obtain the flow field information is to use isothermal flow modeling techniques. This section describes the isothermal modeling techniques applied to the Poplar River Boiler, and summarizes the results of the flow field characterization study. The sorbent injector design also utilize the isothermal model for verification of design concepts, and is an integral part of the isothermal modeling studies. However, a seperate section (Section 6) is prepared for presenting the results of the sorbent injector design.

5.1 Physical Model Description

The physical isothermal model of the Poplar River Boiler was constructed with a 1:24 geometric scale so that the model could be operated within the limits of EERC's testing facilities. Figure 5-1 sketches the configuration of the Poplar River physical isothermal model. The model includes the furnace, the four tube banks of the convective heat transfer zone, and the four burner packs which are located on the corners of the furnace. Figure 5-2 presents a general view of the model in photograph.

The physical model is made of clear acrylic plate and has removable front-wall door for access to the inside. The convective pass tube banks are simulated using two types of materials: 1/8-inch-thick acrylic plates for the secondary superheater ,and 1/4-inch-thick foam core panels for the lower reheater, upper reheater, and the high-temperature primary superheater platens. The burner assemblies are also constructed from acrylic plates, and were placed at the furnace corners in a way that firing angles were maintained. A set of tiltable rectangular slots was placed at the burner exit to allow simulation of the full-scale burner tilt.

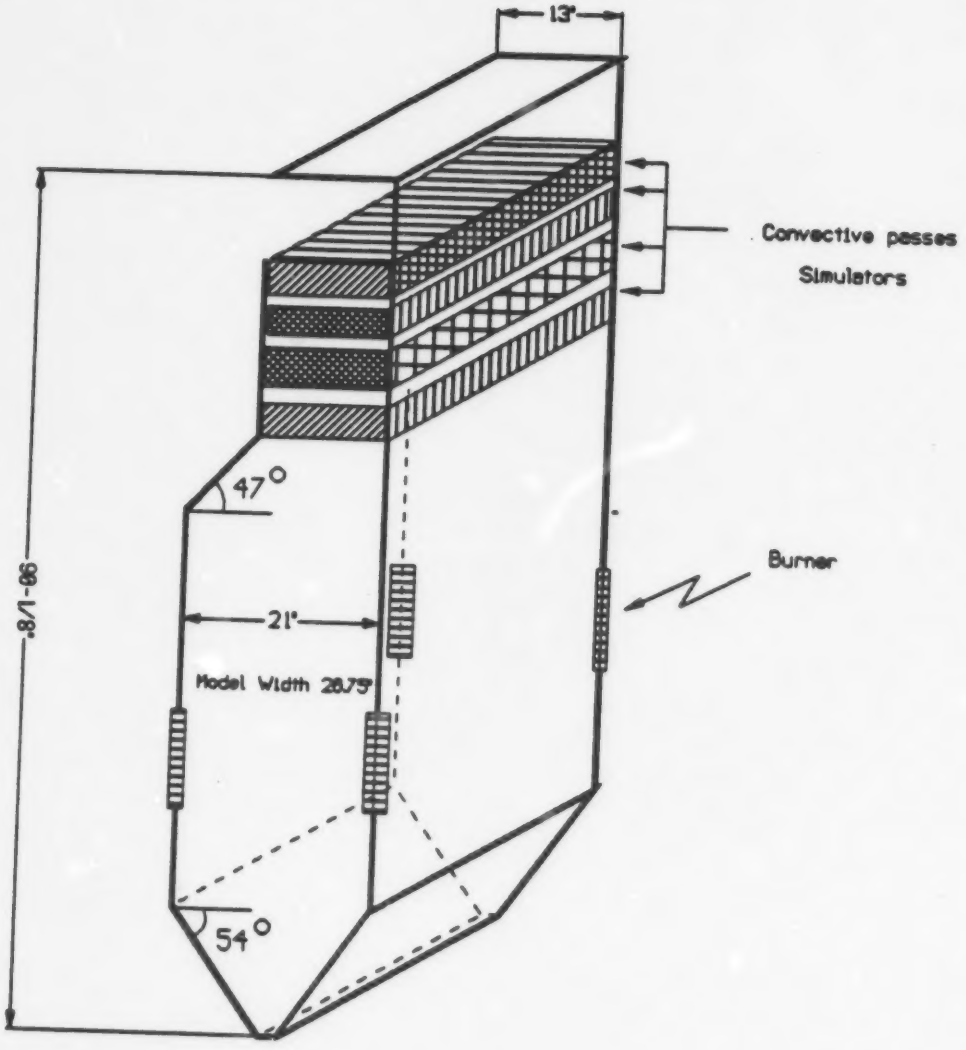

Figure 5-1. Isonetric Sketch of 1:24 Scale Model of Poplar River Boiler

Figure 5-2. General View of Poplar River Isothermal Flow Model

5.2 Model Scaling Criteria

The isothermal flow modeling was conducted based on four scaling criteria in order to maintain similarity of the flow structures between the model and the boiler. The four criteria are geometric, dynamic, Thring-Newby, and pressure-loss similarities. Briefly, geometric scaling was required to maintain similarity of the overall flow patterns. For the Poplar River Boiler, a 1:24 geometric scale was chosen. Dynamic similarity was achieved by maintaining an overall Reynolds' number greater than 15,000, so that similarities in global turbulent flow structures were established. The burner compartments were sized according to a scaling technique first suggested by Thring and Newby (1952), to account for difference between the burner flow density and the furnace gas density in the full-size boiler. In this technique, the burner area is expanded by the ratio of the burner flow density to the furnace gas density, simulating jet expansion phenomena at the burner flame front. In order to maintain the overall burner windbox height and to maintain the centerline elevation of each passage, only the width of each burner passage was expanded. The convective passes of the model were designed to produce pressure-loss coefficients which matched those of the full-scale system. The pressure-loss coefficient was defined as the ratio of the pressure drop across the tube bank to the mean velocity head of the passing fluid flow. By matching the pressure losses across the convective passes, the degrees of flow spreading, straightening, and dampening were correctly simulated.

5.3 Experiment

EERC maintains an air-based physical flow modeling facility for the investigation of aerodynamics within combustion systems. This facility includes the capability to produce and control air flow to models at a rate up to 1200 scfm and to study flow characteristics using a range of diagnostic techniques. These techniques include flow visualization, velocity measurements, and gas concentration measurements. Tracers which can be used include bubbles, smoke, particles, and gases. Over the past several years, the flow modeling facility has been used extensively to study aerodynamics within a range of utility boilers, pilot-scale combustors, and waste incinerators.

The air flow was supplied to the isothermal flow model through eight supply lines between the facility's air-flow distribution manifold and the burner packs: two lines for each burner. The flow in each line was adjusted by a gate valve and metered by a calibrated orifice plate. Characterization of the boiler flow fields involved both qualitative and quantitative techniques. The qualitative technique included smoke and bubble (neutrally-buoyant) injections for flow field visual observation. The quantitative technique employed velocity measurements, which were made over a grid of points at selected horizontal planes. A single-wire, constant temperature, hot-film anemometer was used for the velocity measurements.

5.4 Characterization of Boiler Global Flow Field

Characterization of global flow structure in the Poplar River model was performed at nominal full-load operating conditions, with a -20 degree burner tilt. Figure 5-3 illustrates the observed main flow features in which neutrally-buoyant bubbles were used as flow tracer. In general, the predominant features of the model flow field are typical of tangentially-fired boilers, and are characterized by an strong rotational component to the flow with corresponding highly-turbulent flow in the center of the furnace and high flow near the walls. There are two distinctive flow features in the upper and lower furnaces. The upper and lower furnaces are defined as the furnace regions above and below burner elevations, respectively. In the lower furnace, flow from the lowest burner elevation proceeds tangentially downward near the wall regions, then turns in the hopper, and travels vertically upward in the center region of the furnace. When the flow in the center region of the furnace reaches the burner elevation, it is twisted by the upper-elevation burners' outlets. The flow then make an additional helicoid turn in the upper furnace and enters into the superheater platens. In addition, there were no observable recirculation zones developed near the arch of the boiler.

In the past, the standard scaling approach mentioned in section 5.2 occasionally failed to correctly simulate the tangentially-fired boiler flow field with unusual strong rotational component and a recirculation zone in the center region of the furnace. Since the sorbent injection design procedure depends upon the ability of the isothermal model to accurately simulate the

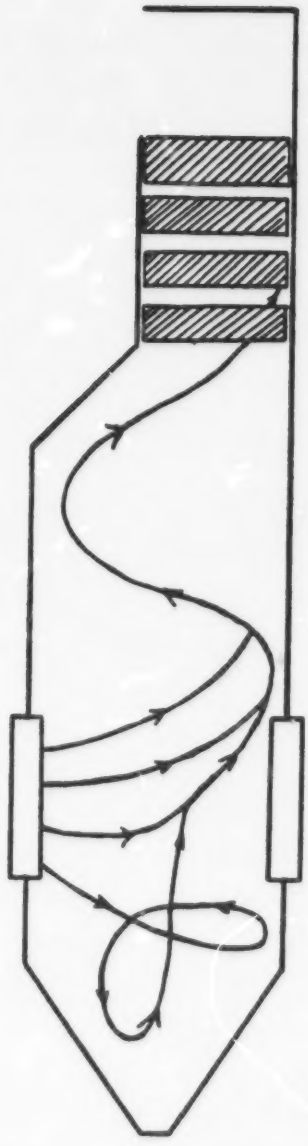

Figure 5-3. Flow Characteristics in the Poplar River Model

boiler flow field, it became necessary to employ an alternate modeling scaling approach when the described flow situation occurred. This approach was based upon the work of Zelkowski (1973) and requires the introduction of a uniform flow of additional air through the furnace hopper. Normally, a detailed velocity measurement is required to assess the adequacy of the isothermal flow modeling criteria, and to evaluate the necessity of the alternate Zelkowski scaling criterion.

Velocity measurements were performed at a horizontal plane near the entrance of the superheater platens (El 804334) as shown in Figure 5-4. A total of 18 measurement locations were chosen, and they are depicted in a figure included in Appendix A. Since the hot wire used for the velocity measurements only applies to one flow direction, special considerations have been given to resolve three velocity components along a retangular coordinate system. The details of the measurement techniques are also documented in Appendix A, along with the measured raw data. Figure 5-4 plots profiles of the normalized vertical components measured at El 804334. It can be seen that the velocity field at this plane was pretty much uniform, other than the fact that the central and the north-east parts of the flow have slightly lower speed than those close to the west and the south-east side of the walls. In view of the uniformity of the flow measured at the convective passage inlet, the Zelkowski scaling approach was not chosen for the current flow modeling.

6.0 SORBENT INJECTION SYSTEM DESIGN

The design of sorbent injection system usually involves specification of several injection parameters. The parameters to be specified are injection location, injector size, number of injectors, and injection velocity, and injector configurations. For an injection system with fixed injector sizes and numbers, the injection velocity, which refers to the velocity of the transport air, can be expressed in terms of percentage of <u>total</u> combustion air (based on design data). Usually, a combined experimental and analytical procedure is required to find optimum sets of sorbent injection parameters for a range of boiler operating conditions. The normal approach is, firstly, to identify a set of candidate injection parameters based on some emperical calculations and the

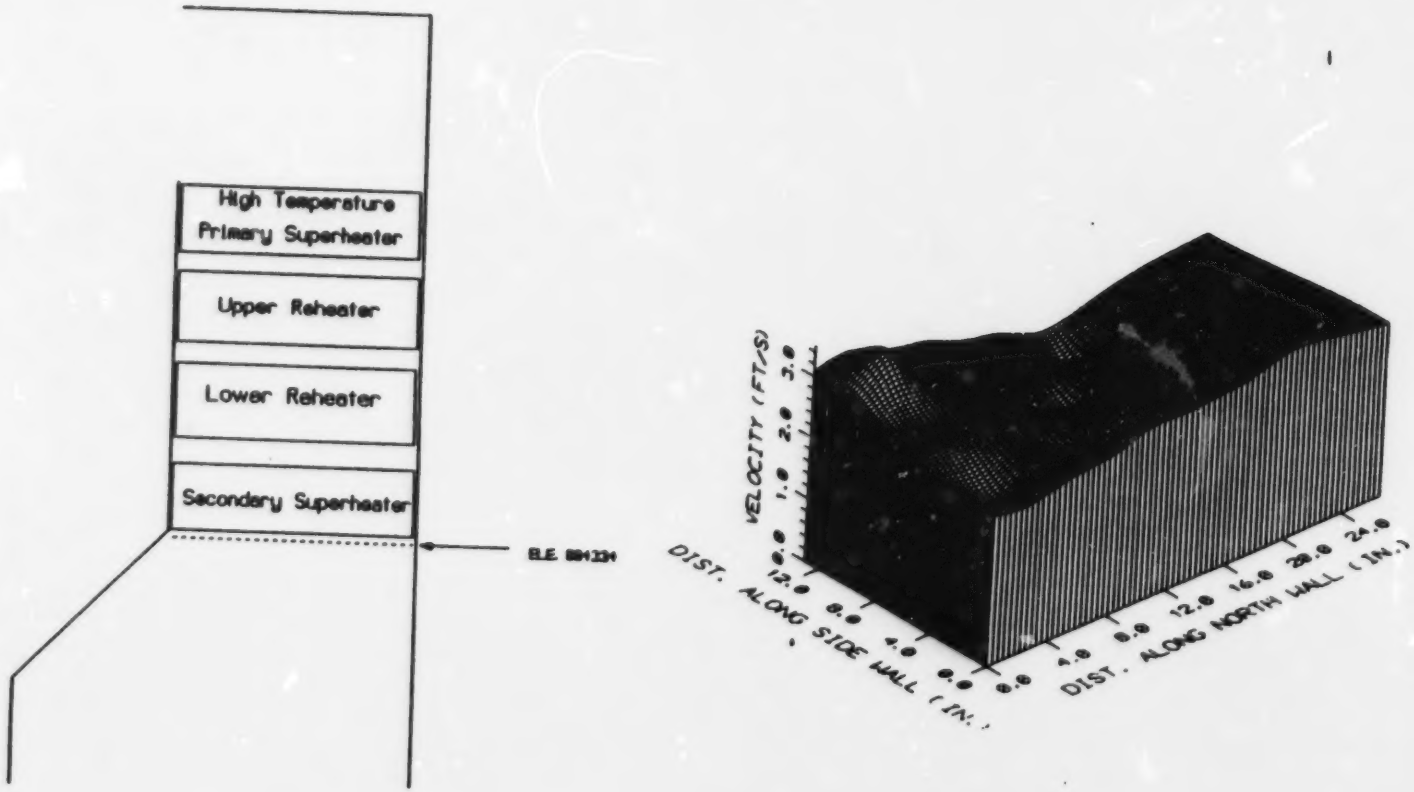

Figure 5-4. Vertical Velocity Profile at Superheater Entrance-Elevation 804334

heat transfer modeling results. The next step is to use flow visualization technique to rapidly screen the candidate injection parameters, so that promising sets of parameters can be selected for final testing. The final stage of the design procedure involves tracer gas dispersion measurements for the selected sets, best injection configurations are then recommended.

Among the injection parameters to be specified, the injection location is predominately determined by the heat transfer modeling studies, and the constraint that existing ports should be considered firstly for sorbent injection. For the Poplar River Boiler, initial design consideration indicated that suitable injection elevations for the high load were at El 804334 and at El 807547, whereas El 800790 was recommended for injection at low load. For the two elevations considered for the high load injection, initial heat transfer modeling results suggested the higher elevation (El 807547) was preferred in terms of flue gas temperature. However, this elevation is between the platen superheater and the reheater tube banks, only a narrow space in the order of 3 ft is available for injector installation. The lower elevation (El 804334) provides more space for placing the high load injectors, therefore, was also selected for study so that suitable injection locations for the high load could be fully explored.

6.1 Presentation Format

Table 6-1 summaries preliminary sets of sorbent injection parameters for study. This table served as a frame for the flow visualization screening test, where smoke was used as a marker gas. Appendix B summaries the results of the flow visualization study in photographic form. A total of eight dispersion measurements were performed in order to finalize sorbent injection designs for the boiler. Of which, five measurements were carried out for the high load at the two recommended elevations, and three measurements were for the low load. The dispersion measurement results and techniques are discussed in Section 6.2, and the raw data are tabulated in Appendix C. Sulfur capture predictions are summarized in Section 6.4 for various boiler operating and sorbent injection conditions.

TABLE 6-1. PRELIMINARY TEST MATRIX FOR SORBENT INJECTION CONFIGURATION DESIGN

TRANSPORT AIR (%)	NUMBER OF JETS	JET DIAMETE (CM)	JET DIAMETE (IN)	JET VELOCITY (M/S)	JET VELOCITY (FT/S)	MOMENTUM FLUX RATIO (J)	MODEL JET DIA. (IN)	MODEL TOTAL JET FLOWRATE (SCFM)
2	4	10.86	4.28	146	479	1821	0.46	11.09
	6	7.66	3.02	196	641	3265	0.33	11.09
	8	5.98	2.36	240	789	4941	0.26	11.09
	12	4.22	1.66	322	1056	8859	0.18	11.09
	16	3.30	1.30	396	1299	13405	0.14	11.09
3	4	14.86	5.85	117	384	1077	0.61	15.17
	6	10.49	4.13	157	514	1931	0.43	15.17
	8	8.19	3.22	193	632	2922	0.34	15.17
	12	5.78	2.27	258	846	5238	0.24	15.17
	16	4.51	1.78	317	1041	7927	0.19	15.17
4	4	18.68	7.36	99	324	734	0.75	19.27
	6	13.18	5.19	132	433	1316	0.53	19.27
	8	10.29	4.05	163	533	1992	0.41	19.27
	12	7.26	2.86	218	714	3571	0.29	19.27
	16	5.67	2.23	268	878	5404	0.23	19.27
5	4	22.38	8.81	86	282	543	0.89	23.37
	6	15.79	6.22	115	378	973	0.63	23.37
	8	12.33	4.85	142	465	1473	0.49	23.37
	12	8.70	3.42	190	622	2640	0.34	23.37
	16	6.79	2.67	233	765	3996	0.27	23.37

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6.2 Flow Visualization

25 photos are included in Appendix B, to document the flow visualization results associated with the variation in sorbent injection parameters. Photos No. 1 to No. 10 presents the results for high load injection at El 804334. Similarily, photos No. 11 to 17 summarize the results for high load injection at El 807547. The low load injection results are summarized in photos form number 18 to 25. The following section briefly discusses the contents of the photos.

High Load Injection at Elevation 804334

At this elevation, the photos can be further grouped into three categories:

- Straight jets
  - --- Variation in transport air percentage, fixed six-jet system (Photo No. 1 to 3)
  - --- Variation in number of jets used, and transport air percentage (Photo No. 4 to 7)

- Tilted jets, fixed six-jet system
  - --- Variation in transport air percentage (Photo No. 8 to 10)

High load Injection at Elevation 807547

At this elevation, both straight-jet and lance injection systems were tetsed. The photos can be categorized as below:

- Straight jets
  - --- Variation in transport air percentage, fixed six-jet system (Photo No. 11 to 13)
  - --- Variation in transport air percentage, fixed eight-jet system (Photo No. 14 to 15)

- o Lance injection
  --- Variation in transport air percentage, fixed lance design (Photo no. 16 to 17)

Low Load Injection at Elevation 800790

At this elevation, injection parameters varied include jet number, size, as well as transport air percentage. The photos can also be described as the following:

- o Variation in transport air percentage
  --- four-jet system (Photo No. 18 to 19)
  --- six-jet system (Photo No. 20 to 21)
  --- eight-jet system (Photo No. 22 to 23)

- o Variation in jet size, fixed eight-jet system (Photo No. 24 to 25)

6.3 Dispersion Measurements

Dispersion measurements were made across three designated planes, and on each plane 24 measurement locations were selected. The three measurement planes were located several feet downstream of the sorbent injection planes at elevations 804334, 807547 (both for high load), and at elevation 800790 (for low load). Figures C-1 to C-3 in Appendix C sketch the relationship of the dispersion measurement planes to planes of the sorbent injection. Figure C-4 shows the measurement locations selected for each plane. In addition, Tables C-1 to C-8 document raw data obtained from the dispersion measurement. Table 6-1 shows a test matrix for the dispersion measurement, in which injector operating conditions are indicated for both the high and the low load cases.

Data Reduction

The dispersion measurements made for the all test conditions were plotted as contours of tracer concentration normalized against the well-mixed tracer concentration. Thus, the smaller the deviation of this ratio from 1.0, the more

TABLE 6-2. GAS DISPERSION MEASUREMENTS TEST MATRIX

LOAD	ELEVATION	NUMBER OF JETS	JET DIA. (in)	JET VEL. (ft/s)	TRANSPORT AIR (%)
HIGH	804,334	8	3.75	775	5.00
HIGH	804,334	6(-30 DEG. TILT)	5.00	468	4.00
HIGH	804,334	6(-30 DEG. TILT)	5.00	580	5.00
HIGH	807,547	8	5.00	440	5.00
HIGH	807,547	LANCE,38	2.50	306	4.00
LOW	800,790	4	4.60	206	2.00
LOW	800,790	6	4.80	188	3.00
LOW	800,790	8	3.60	234	3.00

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uniformly the tracer is dispersed. A measure of the non-uniformity of the tracer concentration over the measurement plane is the coefficient of variation (COV) which is the standard deviation of the concentration measurements divided by the mean concentration. This has been calculated for the dispersion profile and is a measure of the mixedness produced by the injection scheme. In general, good mixing is indicated by low COV's. The closer the COV is to zero, the more uniformly the jet fluid is dispersed.

High Load Dispersion Measurements

A total of five sets of dispersion measurements was performed for the high load case. As shown in Table 6-1, the measurements were made for three different injection schemes at elevation 804334, and for two schemes at elevation 807547. At elevation 804334, all sorbent injection ports were placed along the side walls since the front wall has other boiler components in place and is difficult to access.

At elevation 804334, the smoke injection screening study shows that small injectors with high transport air velocity are needed to provide adequate penetration. Therefore, an initial configuration utilizing eight 3.75-inch jets with injection velocity at 775 ft/s was tested. Figure 6-1 shows the injection configuration and the measured dispersion profiles. The tracer dispersion profiles indicate a poor mixing situation, most likely due to insufficient jet penetrations in regions with higher local fluid velocities. The COV for this injection scheme is 1.06, which is considered to be very high.

In searching for a better injection scheme at elevation 804334 for the high load, a six-jet system, with five of the jets tilted downward 30 degrees, was configured and tested. Figure 6-2 shows the injection scheme and plots the measured dispersion profiles. Note that the jet on the west wall near the rear wall was not tilted downward, but tilted 30 degree toward the front wall to avoid jet impingement on the rear wall. It can be seen that better mixing was achieved with this injection scheme, with a COV of 0.65. However, the dispersion contours also suggest a slight under-penetration of the jets, since a relatively large region with concentrations between 0.5 and 1.0 was developed in the furnace center region.

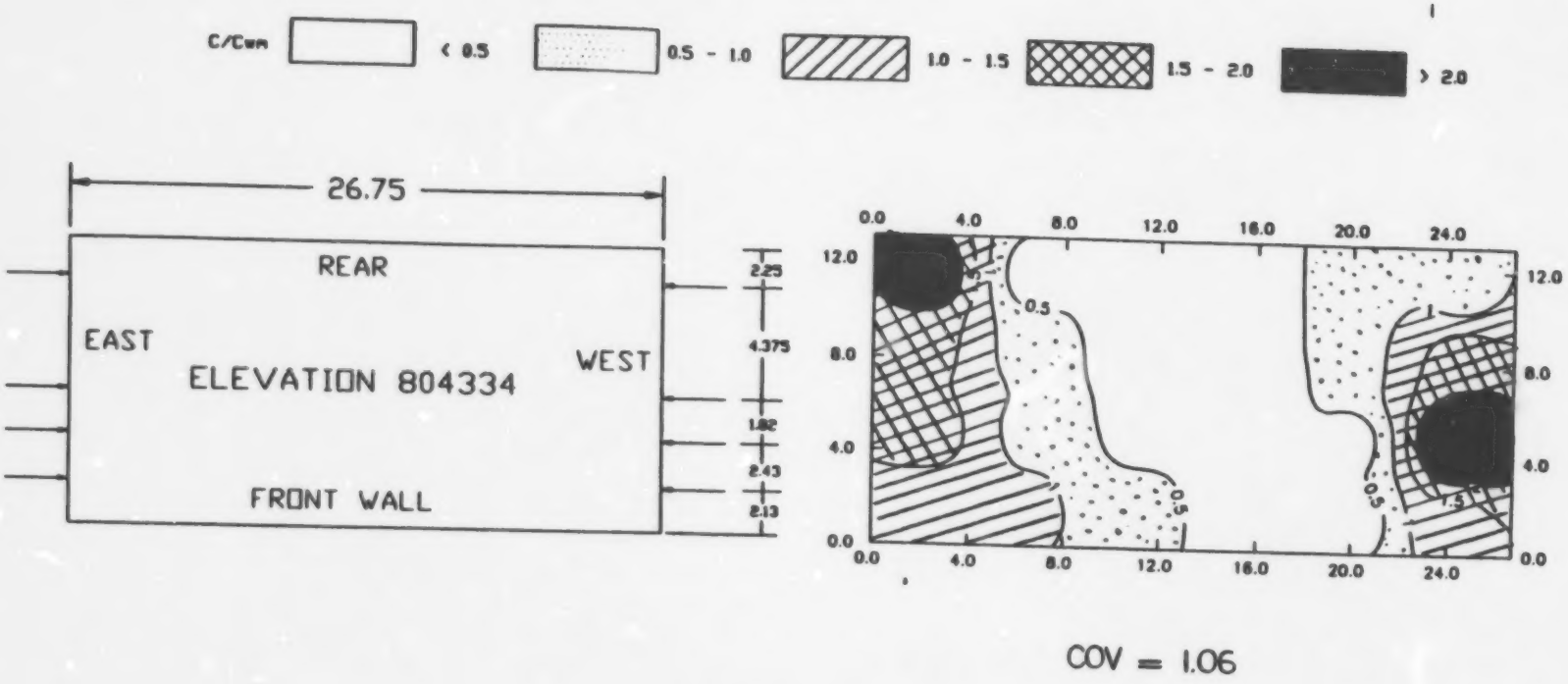


Figure 6-1. Dispersion Profile for High Load Injection at 804334 Elevation with 5% Transport Air (8 Jets, Dj = 3.75 in., and Vj = 775 ft/s)

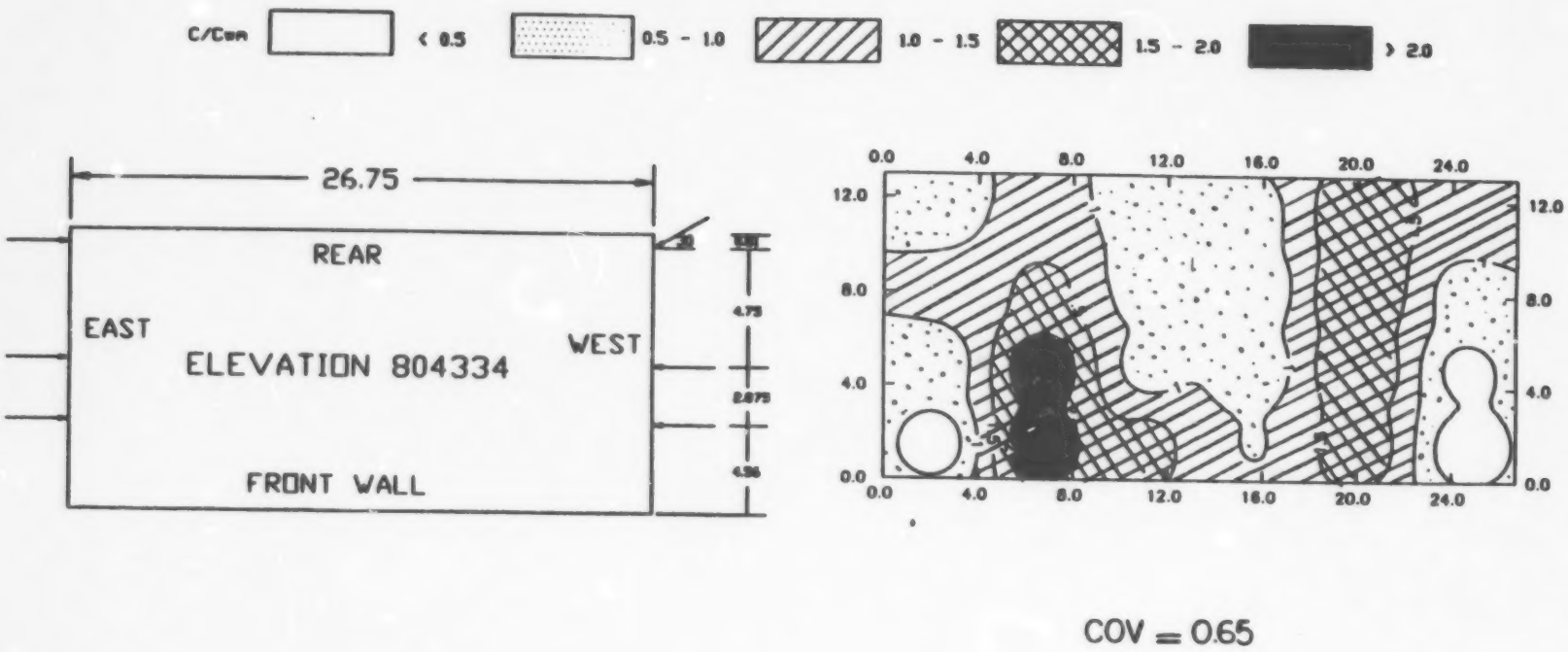


Figure 6-2. Dispersion Profile for High Load Injection at 804334 Elevation with 4 % Transport Air (6 Jets Tilted at -30^{0}, Dj = 5.0 in., Vj = 468 ft/s)

Therefore, a third test with the same injection scheme but at higher jet velocities (transport air increased from 4 % to 5 %) was performed. Figure 6-3 shows the measured concentration profiles, and the injection configurations. The calculated COV is 0.59. As can be seen in Figure 6-3, this set of injection conditions generates the most uniform profiles in comparison to the earlier two profiles (Figures 6-1 and 6-2), therefore, was selected as one of the candidate injection schemes at the high load.

Field characterization measurements showed that temperature at elevation 804334 could be somewhat too high for sorbent injection. Therefore, consideration was given to find an alternate injection elevation based on boiler accessibility . The study suggested elevation 807547, which is located between the superheater and the reheater tube banks, as the alternate injection elevation. A configuration with eight straight 5.0-inch jets and with 5 % transport air was then tested first. The distance between the superheater and the reheater tube banks is narrow, tilting of the sidewall jets was limited and found not to help the jet mixing. Figure 6-4 shows the measured results accompanying with the injection configuration. The contour profiles shown in the figure indicate that jets could only penetrate approximately one-third of the furnace width, even with the large-sized injectors and the high velocity (440 ft/s) employed. There was very little tracer gas detected at the center region of the measurement plane. The COV for this profile is rather high at 0.88.

An attempt to improve the mixing of gas injection at this elevation was conducted by utilizing lance injection. An one-inch model-scale lance tube with 38 openings, each 0.25 " in diameter, was placed through the center of the isothermal model side walls at elevation 807547. Detailed arrangements of the lance opening is shown in Figure 6-5. The configuration was tested with 4 % transport air, and Figure 6-6 shows the result of the test. The figure shows that better mixing can be accomplished at this elevation with the use of the lance, accompanying with a low COV value of 0.54. It should be noted, however, that this brief study does not address other engineering design condiderations related to the lance injection. These considerations would include uniform distribution of the flows through the lance openings, possible cooling requirement for the lance pipe, the impact on the frequency of the soot blowing cycles, tube erosion, and the effort to search for some demonstrated examples

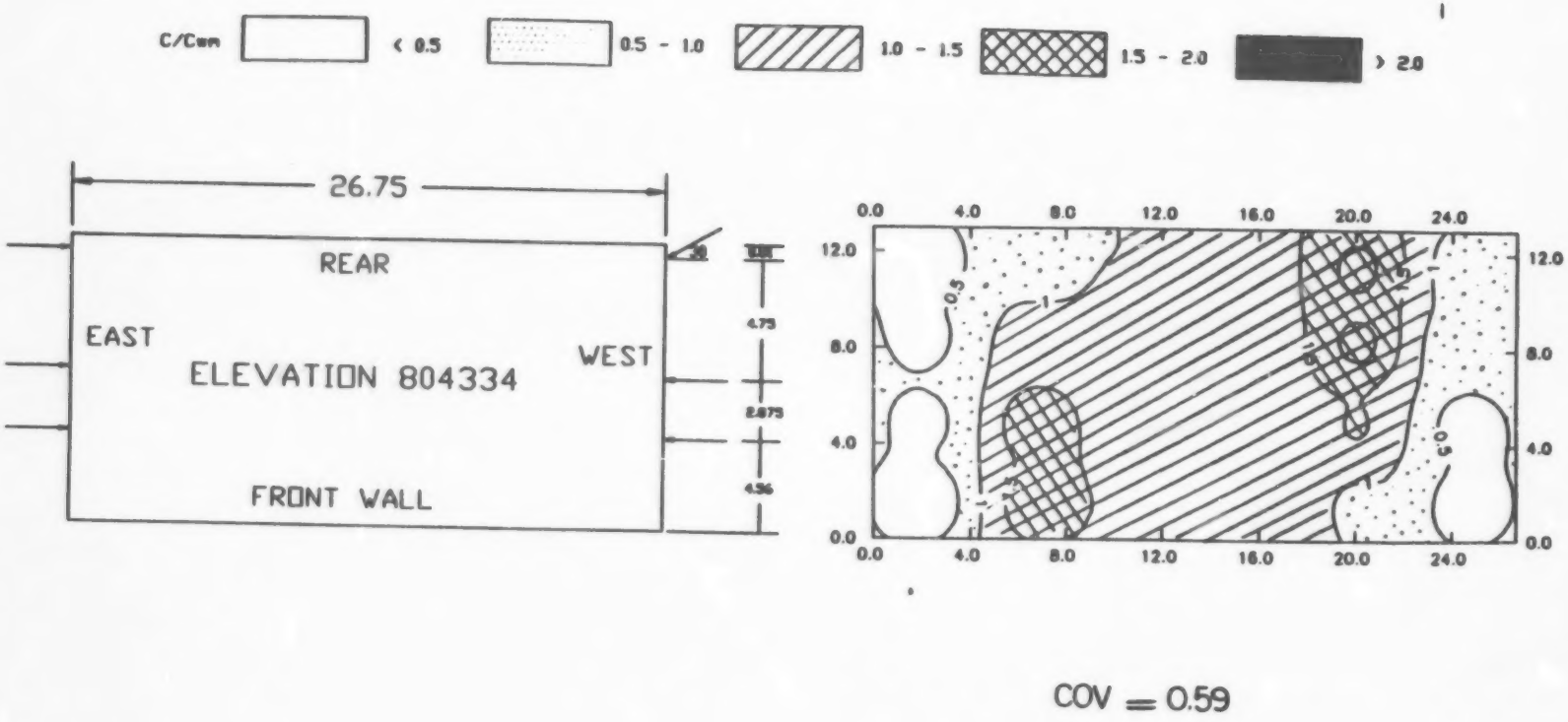


Figure 6-3. Dispersion Profile for High Load Injection at 804334 Elevation with 5% Transport Air (6 Jets tilted at -30^{0}, Dj = 5.0 in, Vj = 580 ft/s)

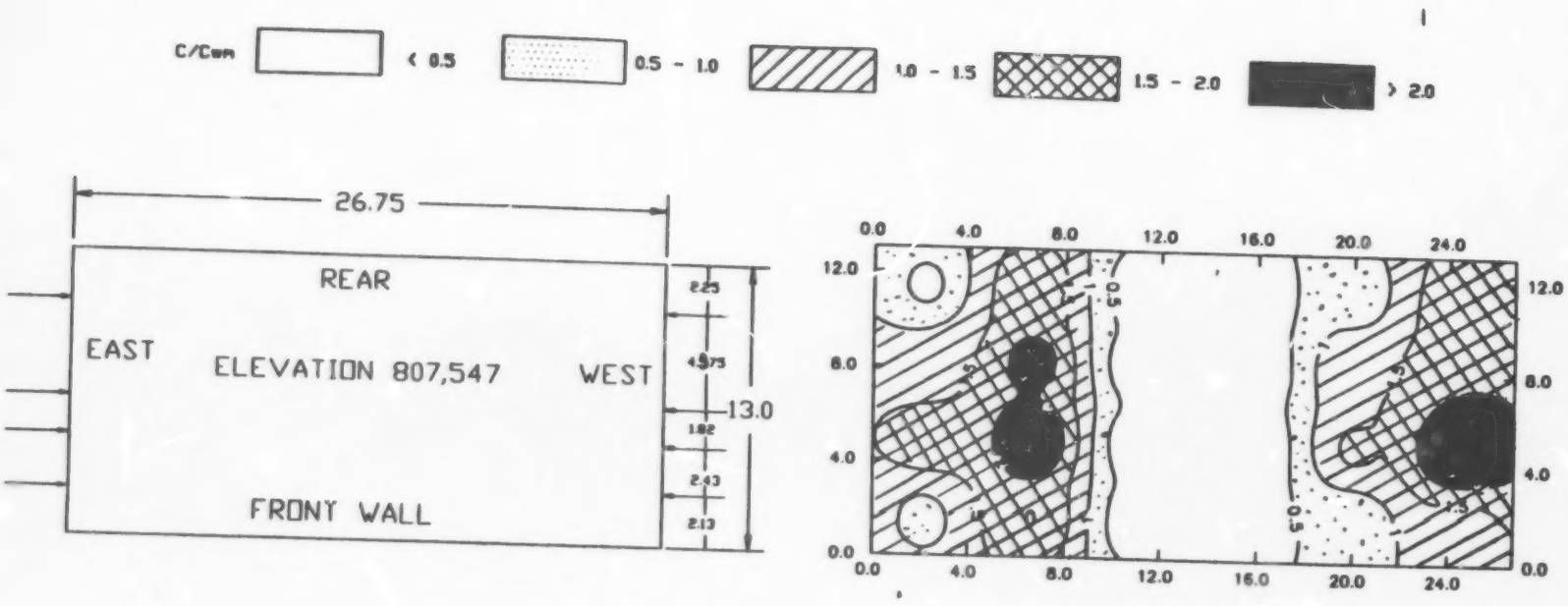


Figure 6-4. Dispersion Profile for High Load Injection at 807547 Elevation with 5 % Transport Air (8 Jets, Dj = 5.0 in, Vj = 440 ft/s)

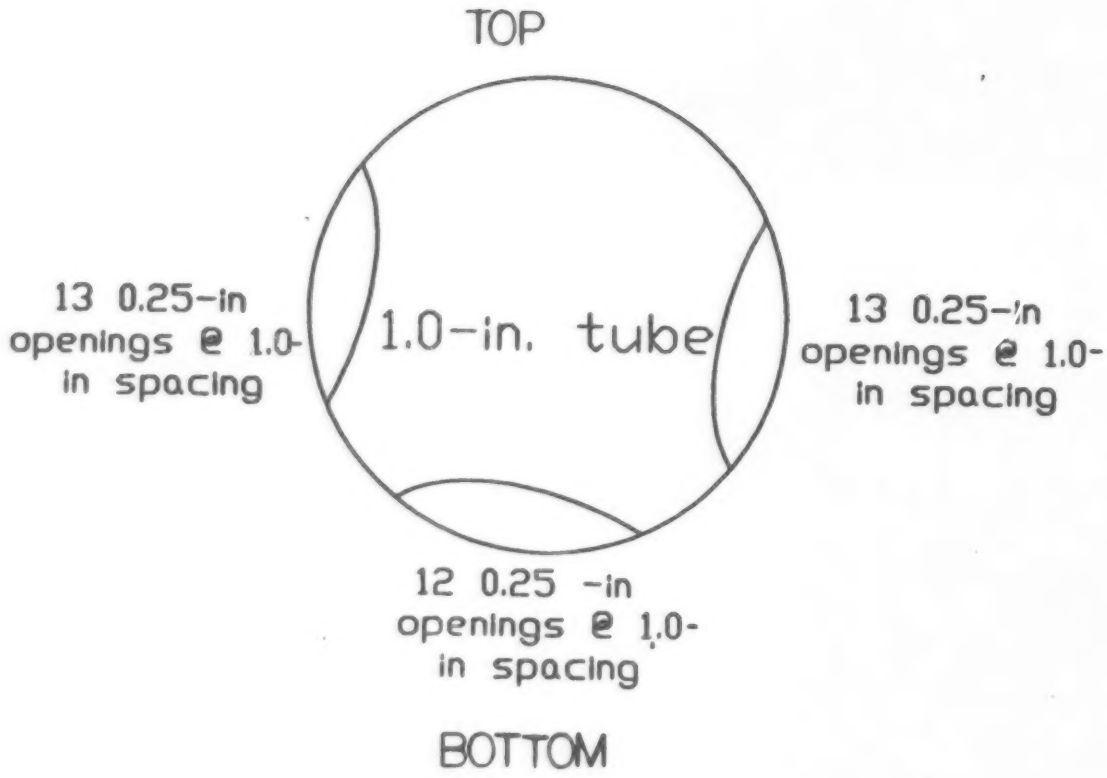
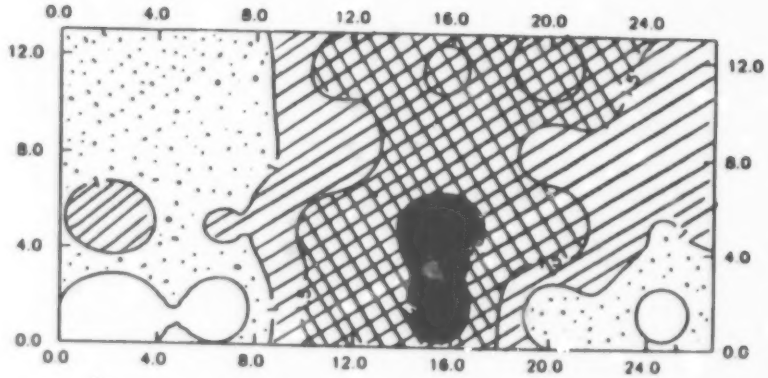


Figure 6-5. Cross-Sectional View for the Arrangement of Openings on the Lance



COV = 0.54

Figure 6-6. Dispersion Profile for High Load Injection at 807547 Elevation with 4 % Transport Air (lance, 38 Jets, Dj = 2.5 in, Vj = 306 ft/s)

which use the lance injection concept. More study effort is required to address these technical issues associated with the lance injection.

Low Load Dispersion Measurement

The low load dispersion measurements were made at elevation 800790 for three injection schemes as described in Table 6-1. The visual observation results suggested that jets at low velocity of approximately 200 ft/s were sufficient to penetrate into the furnace center at this elevation. Therefore, a configuration with four 4.6-inch jets and 2 % transport air was tested first for the low load. The results and the injection configuration are shown in Figure 6-7. It can be seen from the figure that even though the jets were able to penetrate to the furnace center, they did not provide good coverage on the cross-flowing flue gas, evidenced by the lower concentration profiles near the front and the side walls. The calculated COV was 0.77, which is somewhat high.

Thus, a second configuration with six injectors of about the same size and injection velocity was tested. Figure 6-8 shows the injection configuration and the results obtained. Compared to Figure 6-7, the concentration profiles in this figure suggest an improved dispersion and mixing, with the calculated COV at 0.59.

To further improve the spreading of the sorbent jets at low load, higher numbers of jets with smaller sizes are needed. Therefore, a third configuration which uses eight 3.75-inch jets with 3 % transport air was tested. The accompanying injection configuration and the dispersion results are shown in Figure 6-9. As indicated, this injection scheme generates the best flow coverage , and the mixing profiles are shown to be more uniform than those of the two previous injection schemes. The deviation from uniform mixing is the smallest among the three configurations tested, with a COV equals to 0.5.

6.4 Sulfation Model Predictions

The predictions were made for 100%, 75%, and 50% load conditions for different percentages of transport air, and at three injection elevations. Figure 6-10 sketches the locations of the three injection elevations for

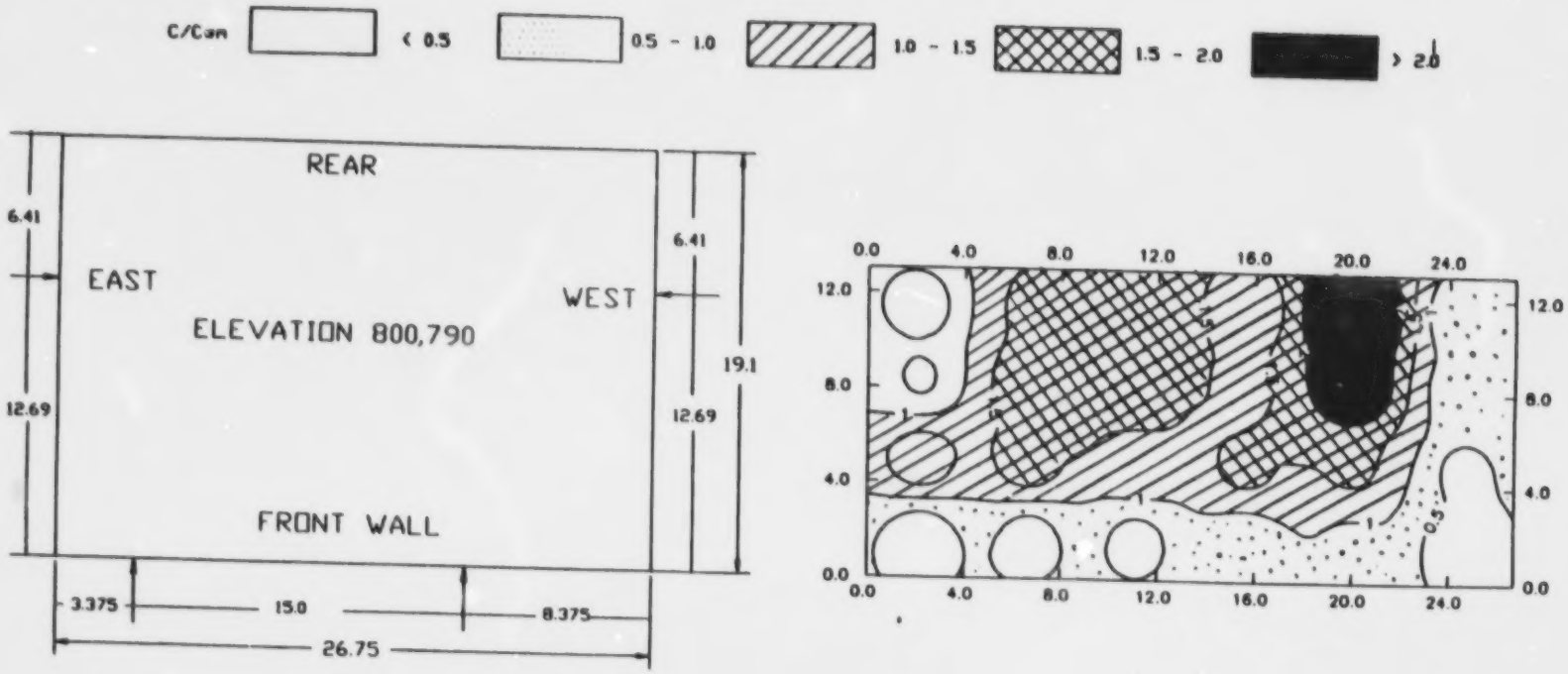


Figure 6-7. Dispersion Profile for Low Load Injection at 800790 Elevation with 2 % Transport Air (4 Jets, Dj = 4.6 in, and Vj = 206 ft/s)

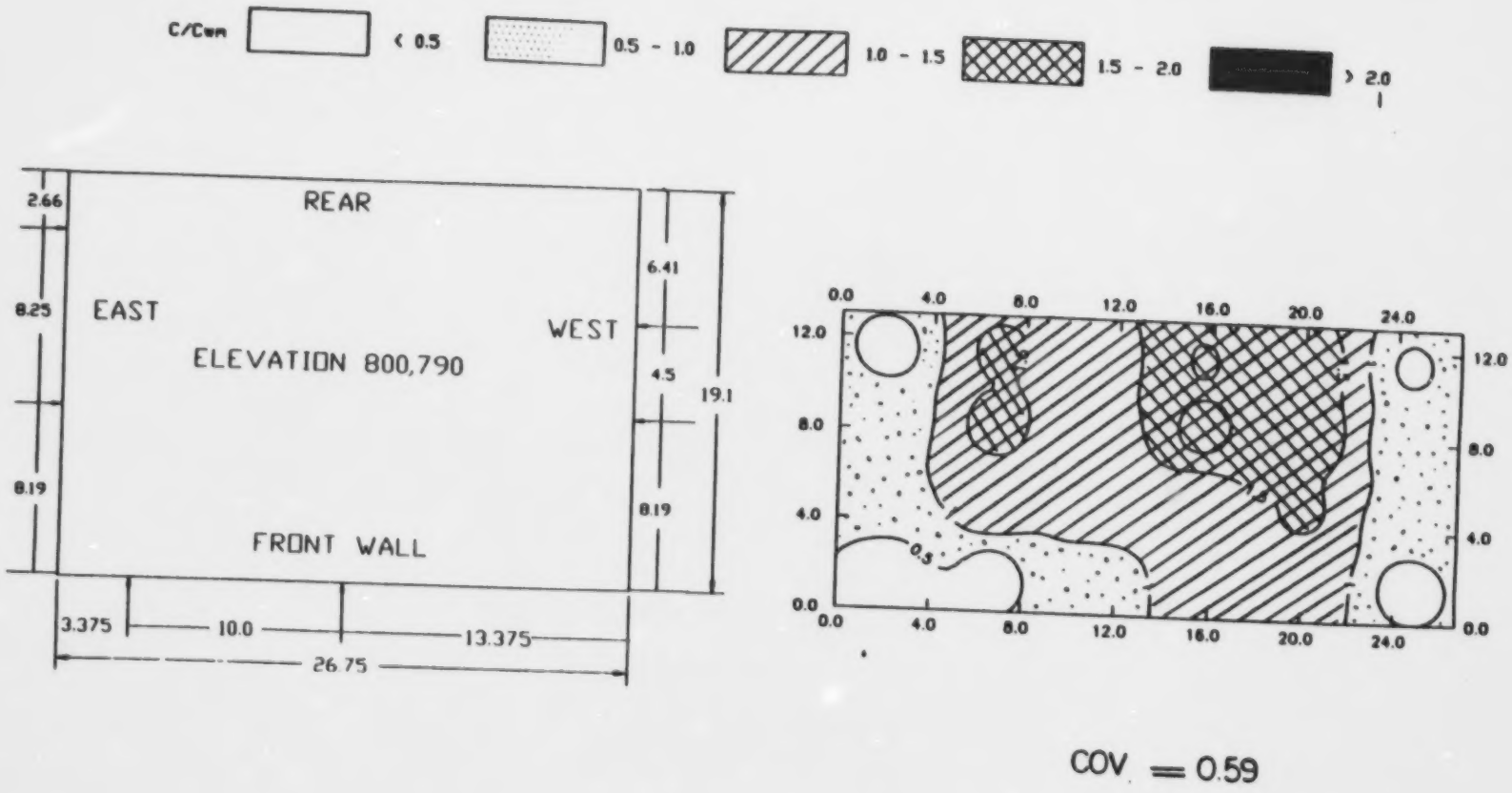


Figure 6-8. Dispersion Profile for Low Load Injection at 800790 Elevation with 3 % Transport Air (6 Jets, Dj = 4.8 in, and Vj = 188 ft/s)

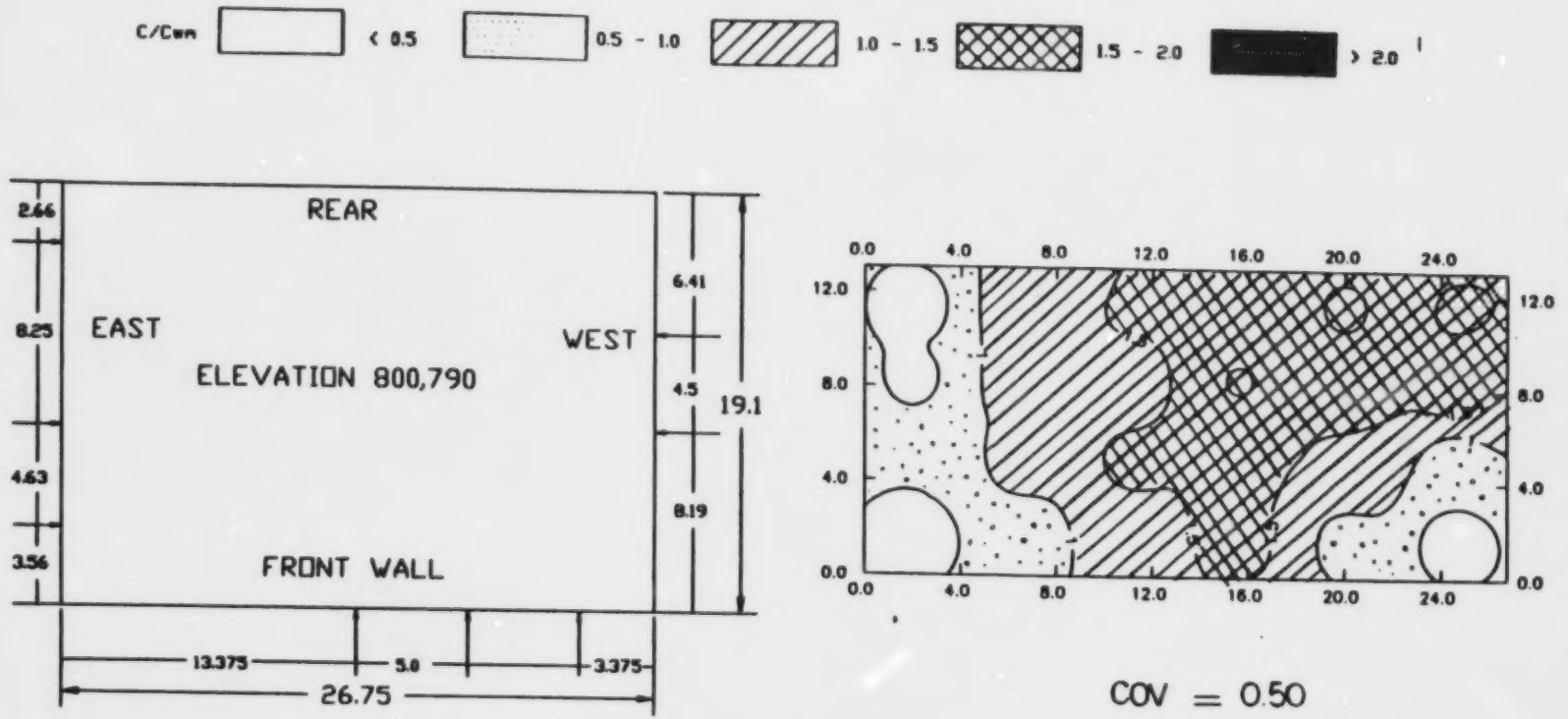


Figure 6-9. dispersion profile for Low Load Injection at 800790 Elevation with 3 % Transport Air (8 Jets, Dj = 3.6 in, and Vj = 234 ft/s)

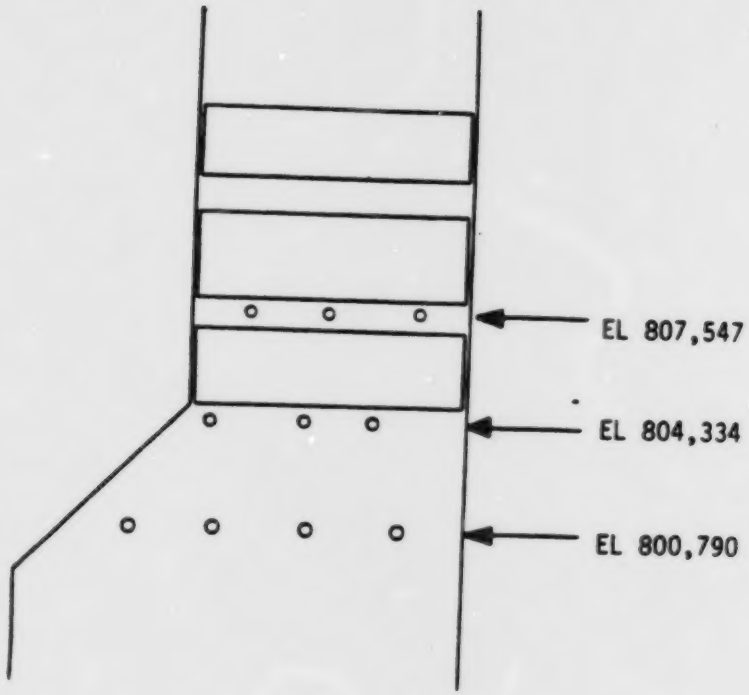


Figure 6-10. Schematic diagram showing injection elevations.

convenience to refer to. The sulfur capture predictions are summarized in Figure 6-11 through Figure 6-15. Note that the available plant air for sorbent transportation as indicated by the Sask Power is equivalent to 0.6 % and 1.1 % transport air, respectively, for the full and the 50% load operations.

The sulfur capture predictions for the high load case are shown in Figures 6-11 and 6-12. In Figure 6-11, capture predictions were shown for injection at El 807547 with the assumption of perfect mixing for the sorbent jets. By comparing these curves with those shown in Figure 6-12, it can be concluded that injection at the lower elevation (El 804334) is more favorable for sulfur removal. Therefore, further analytical work was carried out to evaluate the impact of mixing on sulfur removal at El 804334 and the results are also shown in Figure 6-12. The predictions indicate that 4 to 5 % of transport air is required for optimum jet penetration and sulfur removal. The predictions also suggest that with 0.6 % transport air, sulfur removal (shadded area) would deteriorate due to insufficient jet penetration and dispersion. However, the capture can be improved by using smaller and higher velocity jets with the expense of higher pressure drops. The lower bound of the shadded predictions (0.6 % transport air) corresponds to an injection system using a 5" jet, with an injection velocity of 420 ft/sec, while the upper bound corresponds to a system with six 2" jet and injection velocity at approximately 700 ft/sec.

Sulfur capture predictions for the reduced loads are shown from Figure 6-13 to Figure 6-15. Briefly, the results (see Figure 6-13) suggest that 3 % transport air is required for maximum SO_2 removal at 50 % load. For 75 % load, the results (see Figures 6-14 and 6-15) indicate elevation 804334 is preferred for sorbent injection. At the lower elevation (El 800790, see Figure 6-15), the gas temperatures are relatively too hot so that sulfur captures are predicted to drop. The hotter gas temperature at this elevation also manifest itself by showing higher sulfur captures when the transport air was increased from 0.8 % to 3 %. This is because the furnace gas was cooled down to a more favorable condition accompanied with the 3 % air injection.

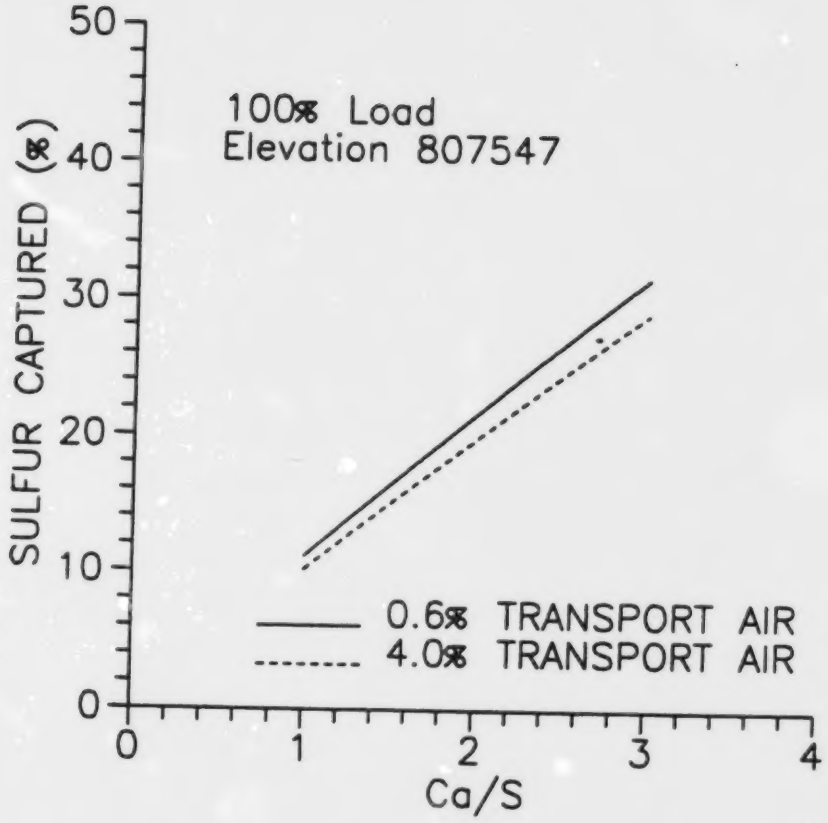


Figure 6-11. Sulfur capture predictions at full load, EL 807547.

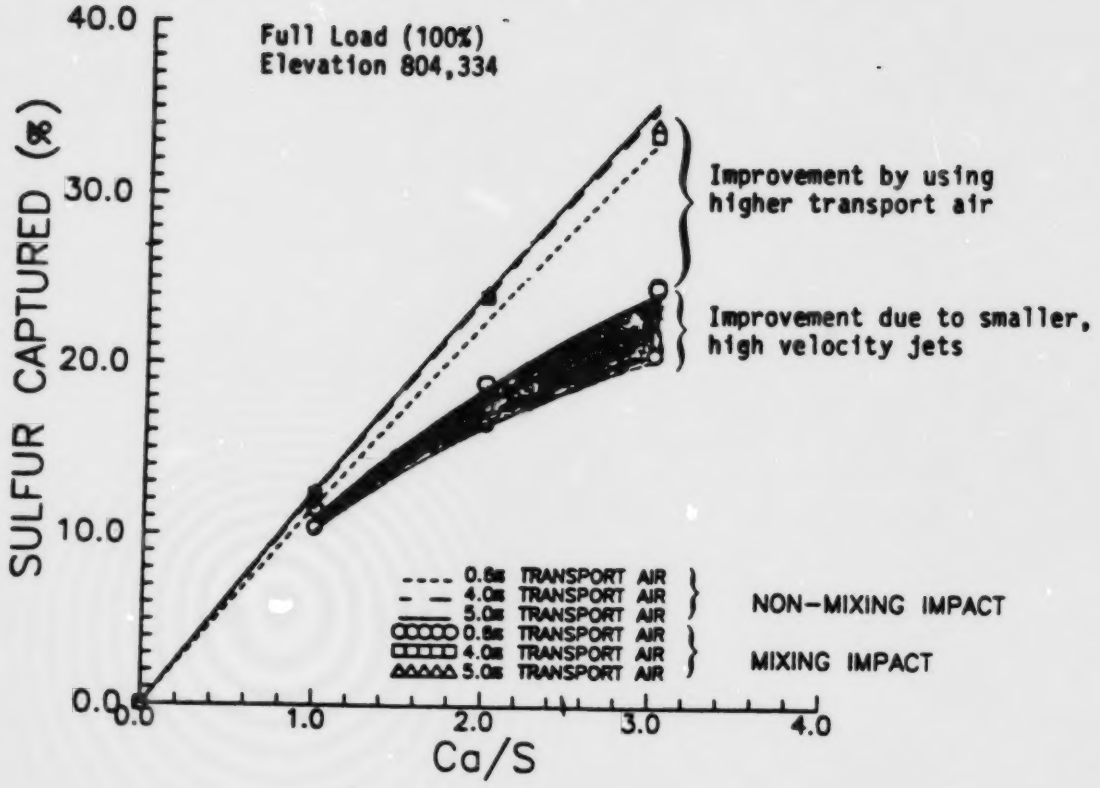


Figure 6-12. Sulfur capture predictions at full load.

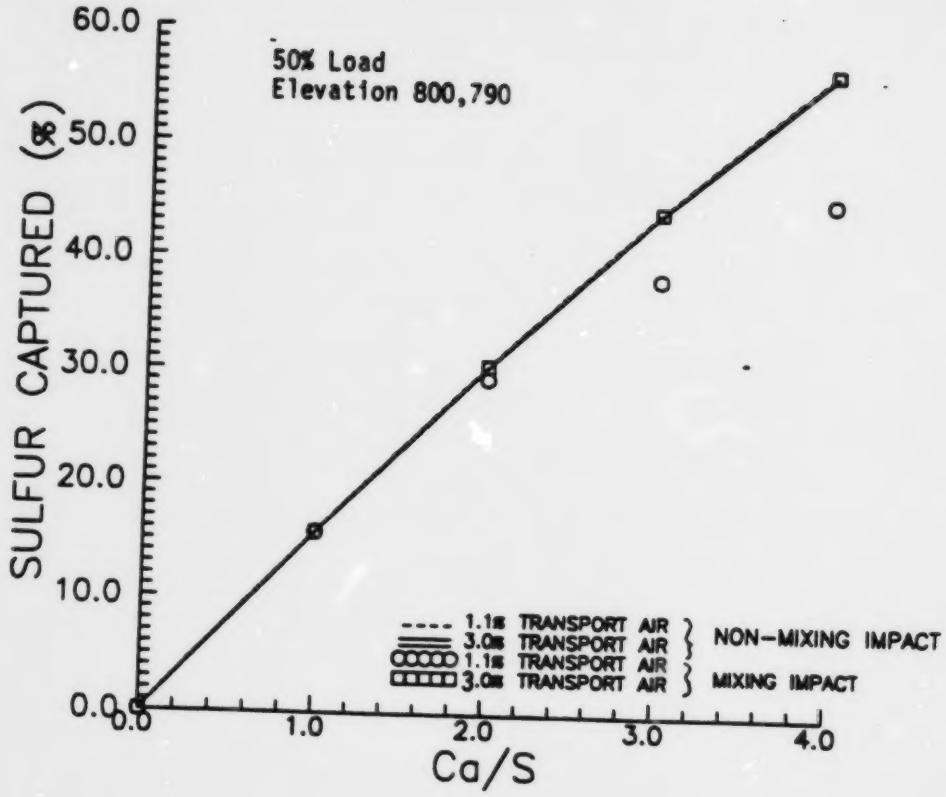


Figure 6-13. Sulfur capture predictions at 50% load.

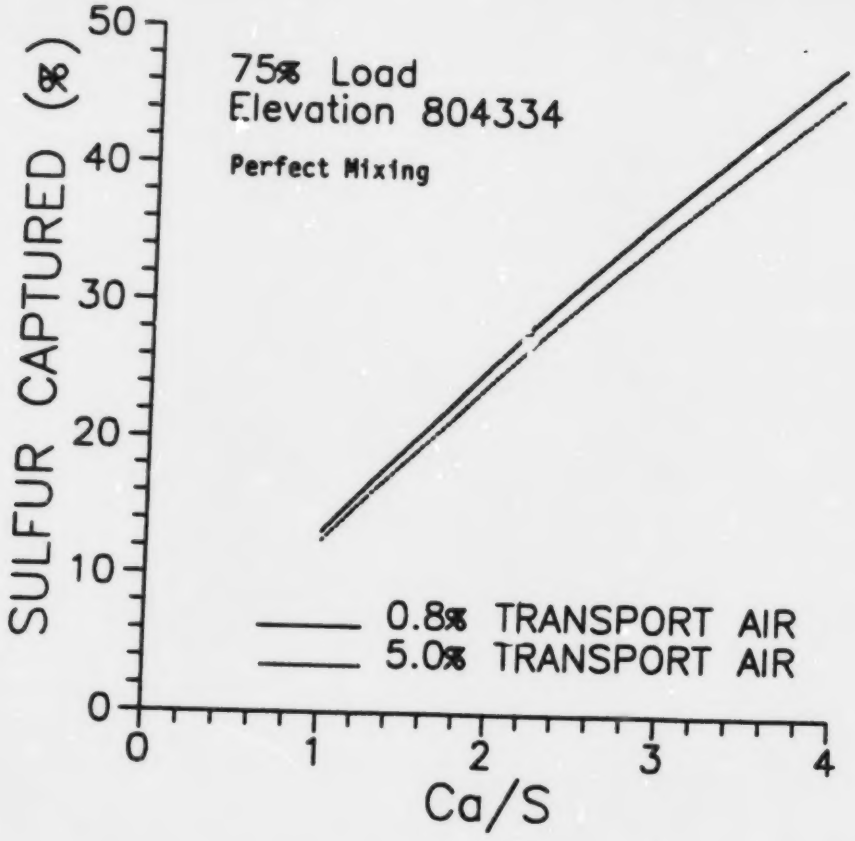


Figure 6-14. Sulfur capture predictions at 75% load, el 804,334.

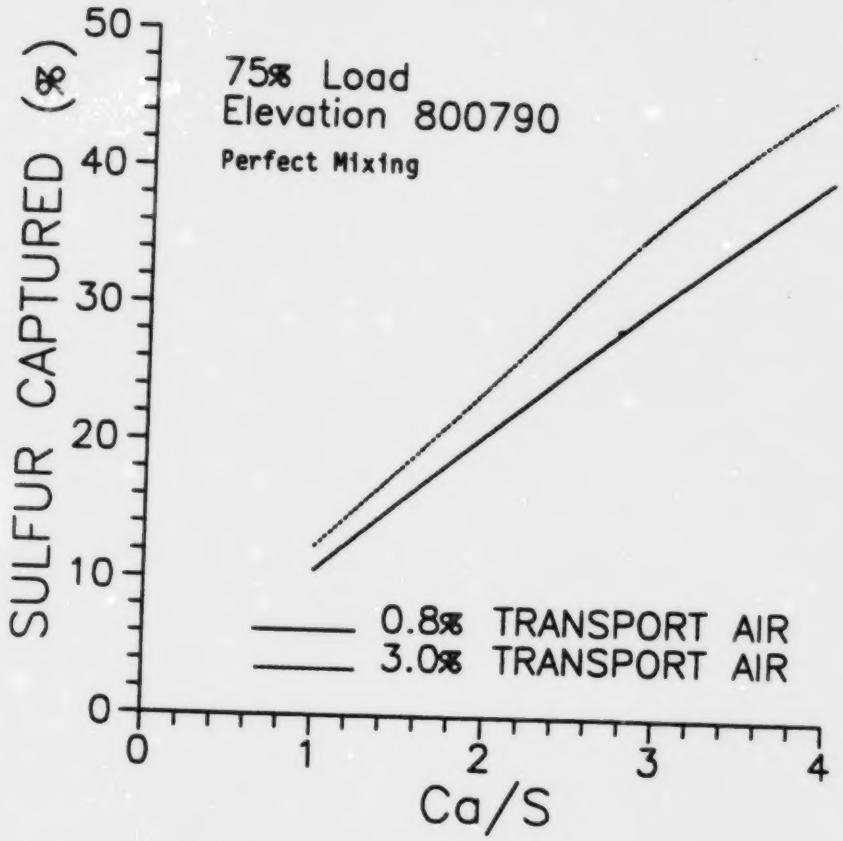


Figure 6-15. Sulfur capture predictions at 75% load, el 800,790.

7.0 SUMMARY

In summary the following points can be drawn from this design study:

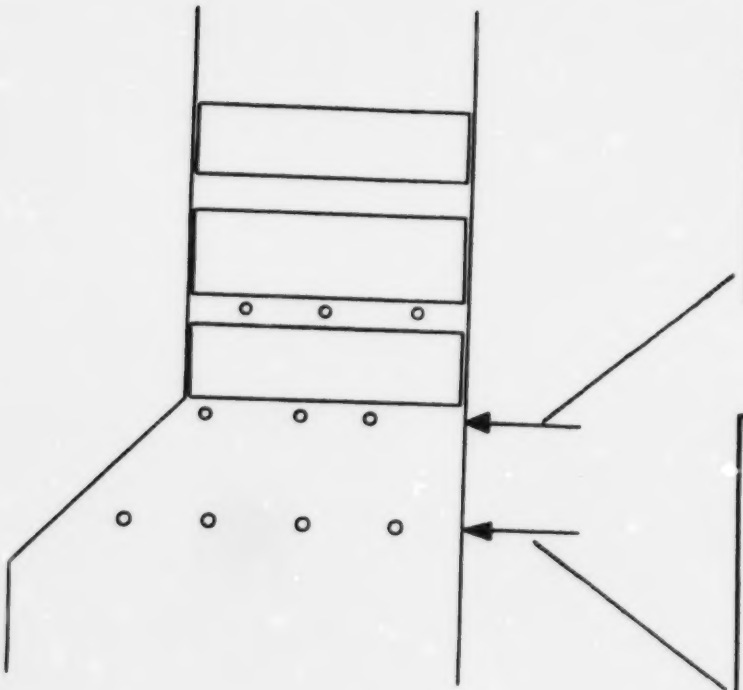
- For the high load injection, a system using six injectors at El 804334 is recommend. Details of the injector arrangements are shown in Figure 6-3, and the nominal injection parameters (5 % transport air) are indicated in Figure 6-16. The photograph described in Appendix B, No. 10, shows the jet penetration and dispersion characteristics corresponding to this injection scheme.

- For the high load injection configuration as specified above, the transport air may be reduced to 4 %. The sulfur capture calculations (Figure 6-12) show the same levels (e.g. 24 % capture at Ca/S = 2) of sulfur removal can be achieved when the transport air is reduced from 5 % to 4 %. The photograph shown in Appendix B, No. 9 and the dispersion profiles shown in Figure 6-2 document the jet penetration and dispersion characteristics corresponding to this set of injection conditions.

- Results from lance injection study at elevation 807547 are summarized in photo No. 16 to No. 17 (Appendix B), and in Figures 6-4 to 6-6. In general, a 4 % transport air is required for sufficient dispersion of the lance jets. The model lance also shows non-uniform distribution of the flows through the lance openings.

- For the lance injection concept, considerations should also be given to other engineering design issues such as tube erosion and possible cooling requirements for the lance tube.

- For the 50 % load injection, a system with 8 injectors at El 800790 is recommended. Details of the injection configuration can be found in Figure 6-9, and Figure 6-16 also shows the nominal injection parameters obtained. The photograph described in Appendix B, No.24, shows the aerodynamic characteristics of the sorbent jets.



HIGH LOAD (100%)

- ELEVATION 804334
- SIX 5.0" INJECTORS
  - 580 FT/S
  - FIVE JETS TILTED @ -30°
  - ONE JET TILTED 30° TOWARD FRONT WALL
  - 3.3 PSI PRESSURE DROP AT NOZZLE
- TRANSPORT AIR IS 5% OF TOTAL COMBUSTION AIR (28,200 SCFM)

LOW LOAD (50%)

- ELEVATION 800790
- EIGHT 3.75" INJECTORS
  - 234 FT/S
  - FIVE JETS ON SIDE WALLS
  - THREE JETS ON FRONT WALL
  - 0.5 PSI PRESSURE DROP AT NOZZLE
- TRANSPORT AIR IS 3% OF TOTAL COMBUSTION AIR (8,500 SCFM)

Figure 6-16. Summary of sorbent injection system specifications for Poplar River Unit 1.

- For the 75 % load operation, elevation 804334 is preferred for injection. The high load injection scheme specified above should be used, with reduced transport air percentage.

- The design study reveals that for uniform dispersion of sorbent jets and for maximum in-furnace SO_2 removal, 3 % transport air is needed for the low load injection, while 4 to 5 % air is required for the high load. SASK power has indicated a 8" pipeline with 1600 liter/sec of air flow is available near the boiler unit. The available air is equivalent to 0.6 % transport air at the high load, and to 1.1 % of transport air at the 50 % load. Maximum sulfur removal (e.g. 18 % removal at Ca/S = 2) may be obtained with an injection system similar to the high load specification, but with jet diameter reduced to 2" in diameter and injection velocity increased to about 700 ft/sec (see Figure 6-12).

- An economic analysis would be required to address the necessity of supplying the additional sorbent transport air. This design study has not considered economic factors which would impact the cost of sulfur removal and power generation.

APPENDIX A
VELOCITY DATA

A. VELOCITY MEASUREMENTS

A.1 Measurement Grids

Velocity measurements in the Poplar River model were conducted over a 3x6 grid of points at superheater plane. The layout of the measurement grid is shown in Figure A-1.

A.2 Measurement Technique

The velocity measurements were made by placing a single sensor hot film anemometer probe at a point in the measurement grid and then orientating the probe perpendicular to the mean flow direction as determined from tuft measurements. Measurements were made from the model front wall. However, at some locations where the probe inserted from the front wall could not be orientated to be perpendicular to the flow direction, the local velocity was replaced by measurements with the probe inserted from the side wall. The recorded data included local mean velocity, standard deviation about the mean value, and turbulence intensity which is the ratio of standard deviation over the mean.

In order to resolve the single-point velocity measurements, tuft measurements were made by placing a feather-tuft probe at the corresponding measurement point. The flow direction was the obtained by recording the projected flow angle on planes viewed from the front wall and the side wall.

The velocity was then used to reduce the data as described in the next section.

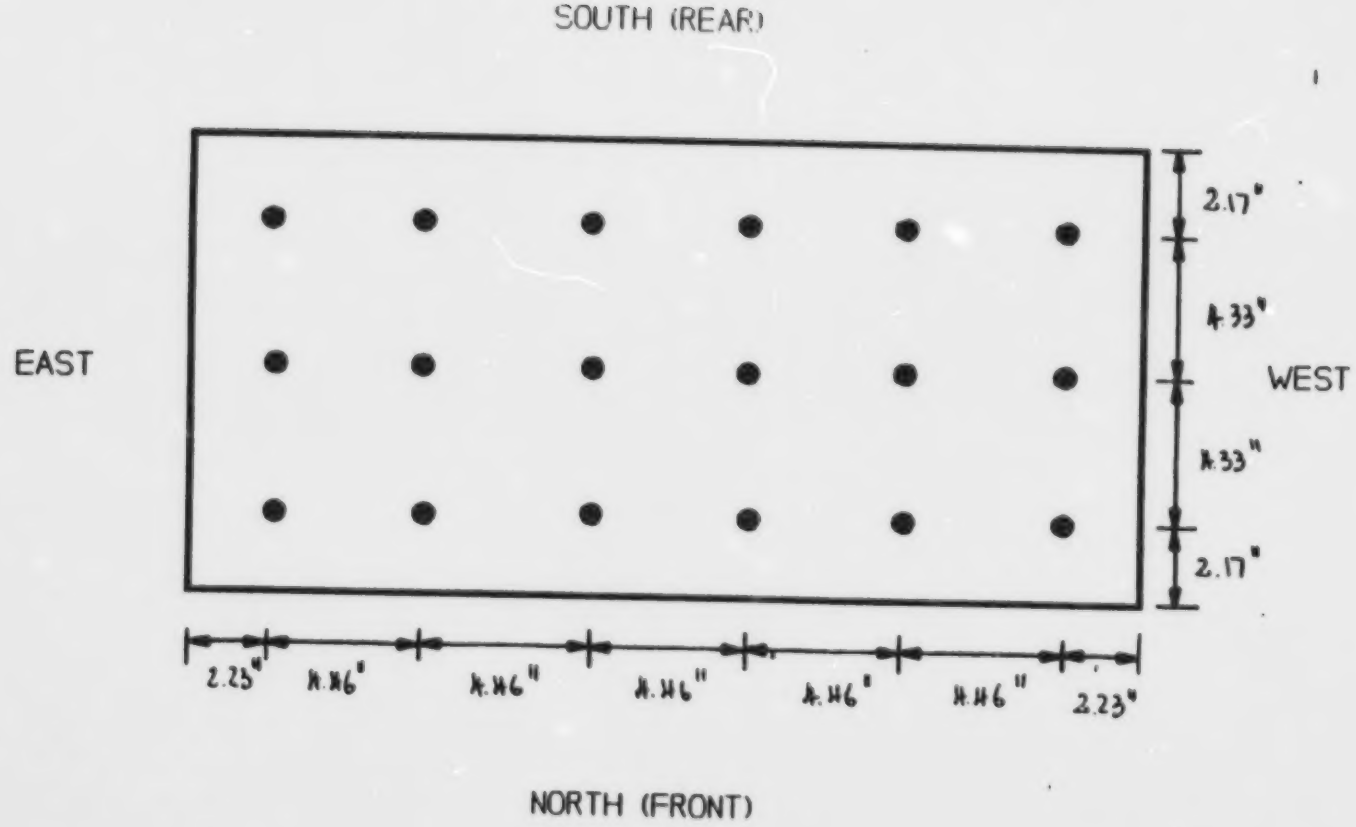
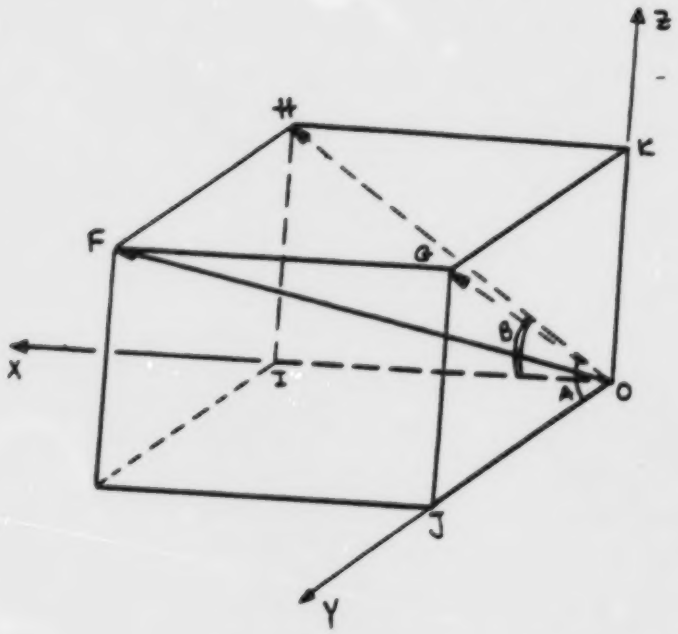


Figure A-1. Velocity measurement grid points.

A.3 Data Reduction

The orthoganal components of the velocity vector are obtained by combining the magnitude measured with the hot wire anemometor and the flow direction observed from the tuft measurements. The data were reduced according to the following vector projection.



Where: $\vec{OF}$ is velocity vector (measured data),
$\vec{OH}$ is projected vector of $\vec{OF}$ on ZX plane (viewing from side wall)
$\vec{OG}$ is projected vector of $\vec{OF}$ on Y2 plane (viewing from front wall)
A is angle of $\vec{OG}$ with horizontal surface (obtained from tuft meas.)
B is angle of $\vec{OH}$ with horizontal surface (obtained from tuft meas.)

The following formula are then used to determine the magnitude of vectors $\vec{OI}$, $\vec{OJ}$, and $\vec{OK}$:

Since $OF = \sqrt{OI^2 + OJ^2 + OK^2}$ (1)

$OK = OG \sin A$ (2)

$OJ = OG \cos A$ (3)

$OI = OH \cos B$ (4)

and $OH = OG \frac{\sin A}{\sin B}$ (5)

It can be shown that

$$OJ = \frac{OF \cos A}{\sqrt{(\cot B \sin A)^2 + 1}} \quad (6)$$

$$OK = \frac{OF \sin A}{\sqrt{(\cot B \sin A)^2 + 1}} \quad (7)$$

$$OI = \frac{OF \cot B \sin A}{\sqrt{(\cot B \sin A)^2 + 1}} \quad (8)$$

After the X, Y, Z components were determined for each point, the component profile was normalized according to the following formula:

$$V_{ni} = \frac{V_i}{V_i A_i / \Sigma A_i}$$

where: V_{ni} = Normalized velocity at point i, dimensionless
V_i = Velocity at point i, ft/s
A_i = Area of Zone i, ft^2

For the Poplar River model, the directional orientation for the velocity data analysis is as following:

FRONT WALL

Table A-1. Velocity Data Measured at Elevation 804334

VELOCITY COMPONENT ANALYZER

PLANE : EL 804334
TOTAL FURNACE FLOW (SCFM) : 400
VELOCITY METER : HOT FILM ANEMOMETER 1050
SENSOR : 1220-20

DATE : 11-29-89
CONDUCTED BY : JDM
BURNER TILT : -20 DEGREES
TEST CONDITIONS : FULL LOAD

1. RAW DATA:

		1	2	3	4	5	6
1	VELOCITY	5.050	4.271	3.253	2.599	3.242	3.680
	ANGLE A	125	110	90	90	60	60
	ANGLE B	125	135	130	135	130	130
	AREA	0.093	0.093	0.093	0.093	0.093	0.093
2	VELOCITY	3.889	3.977	3.153	4.148	4.540	4.805
	ANGLE A	135	135	130	60	50	60
	ANGLE B	80	110	120	135	120	130
	AREA	0.093	0.093	0.093	0.093	0.093	0.093
3	VELOCITY	3.103	3.553	4.253	4.203	4.741	4.937
	ANGLE A	135	135	70	45	50	45
	ANGLE B	80	60	45	70	60	70
	AREA	0.093	0.093	0.093	0.093	0.093	0.093

Table A-1. continued

2. RECTANGULAR COMPONENTS:

		1	2	3	4	5	6
1	X	-2.513	-2.925	-2.091	-1.838	-1.906	-2.163
	Y	-2.513	-1.065	0.000	0.000	1.311	1.488
	Z	3.588	2.925	2.492	1.838	2.271	2.578
2	X	0.481	-0.991	-1.275	-2.715	-1.836	-2.825
	Y	-2.729	-2.723	-1.854	1.568	2.669	1.944
	Z	2.729	2.723	2.209	2.716	3.181	3.366
3	X	0.384	1.343	2.912	1.048	1.918	1.231
	Y	-2.177	-2.326	1.060	2.878	2.787	3.381
	Z	2.177	2.326	2.912	2.878	3.321	3.381

APPENDIX B. FLOW VISUALIZATION RESULTS

(Photos are not bound with the report)

APPENDIX C
DISPERSION DATA

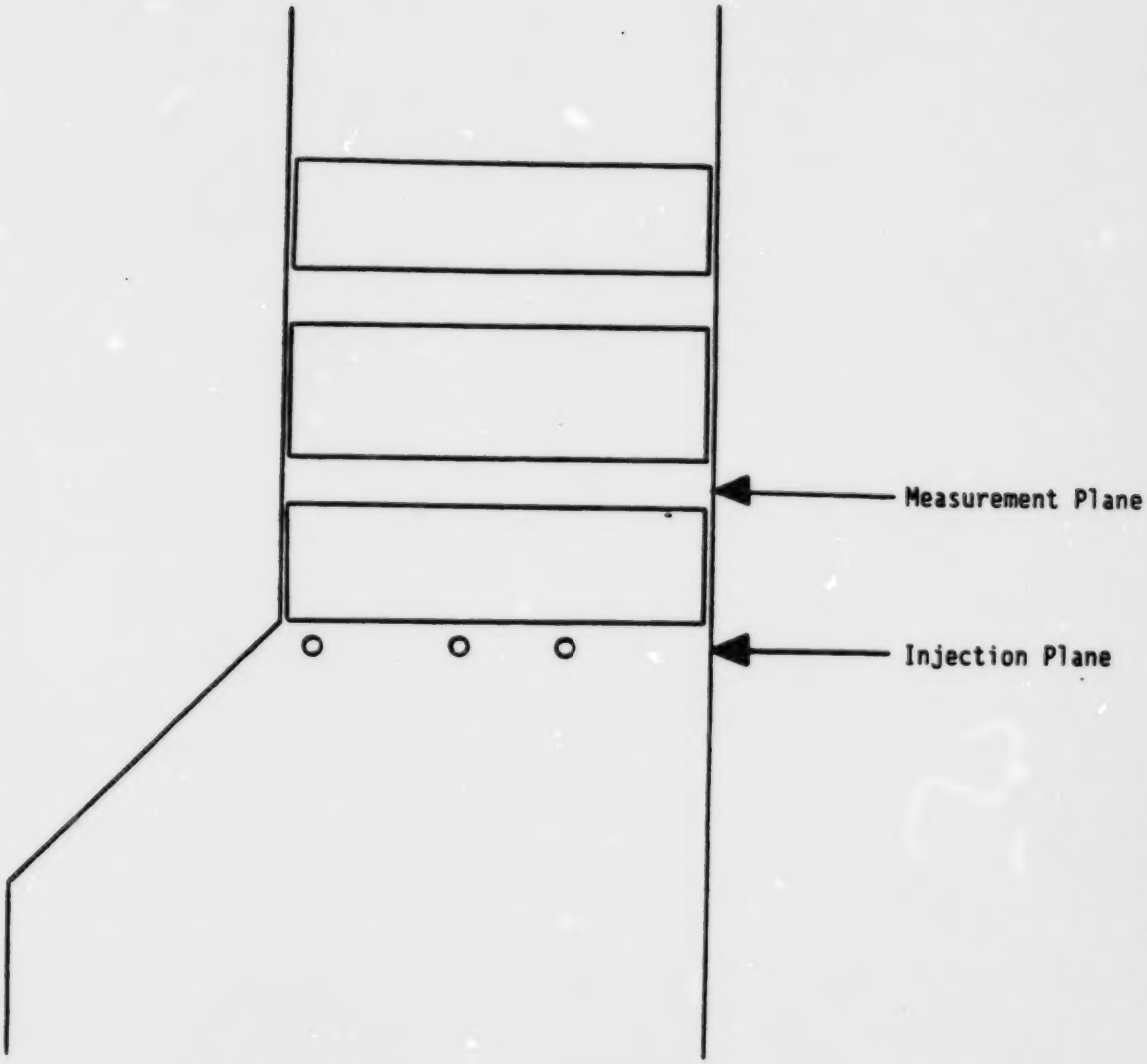


Figure C-1. Measurement Plane for Injection at Elevation 804334

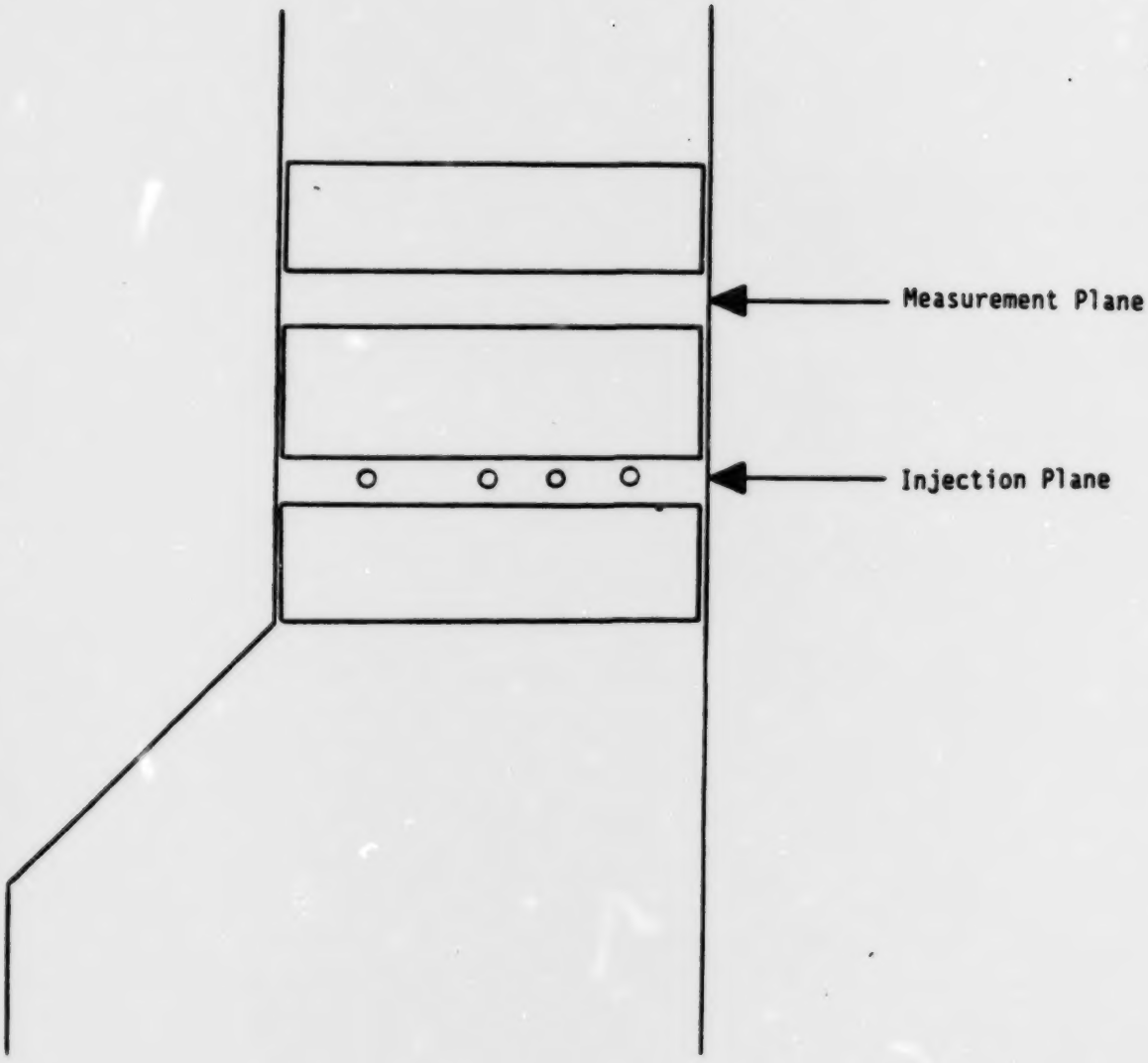


Figure C-2. Measurement Plane for Injection at Elevation 807547

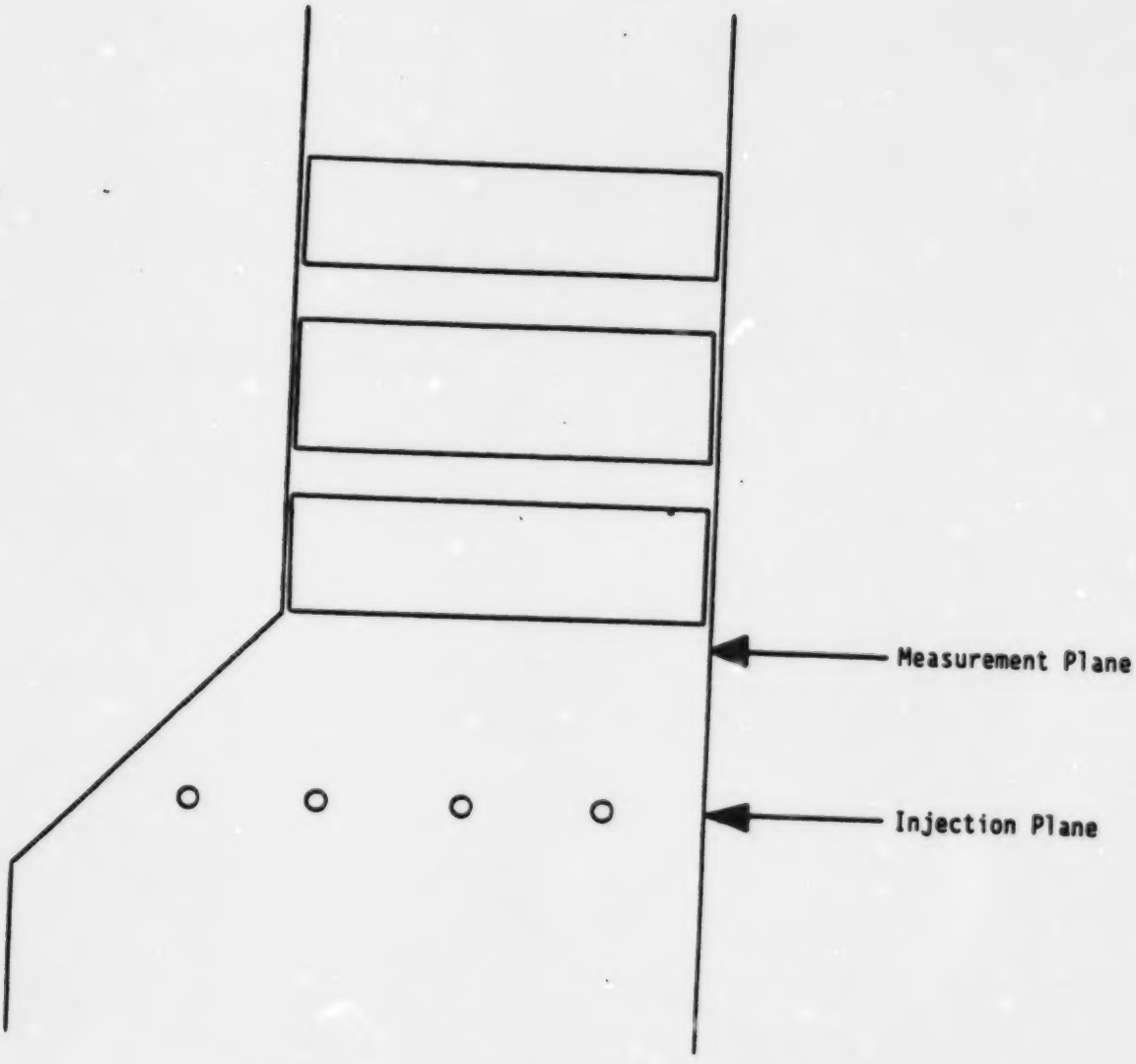


Figure C-3. Measurement Plane for Injection at Elevation 800790

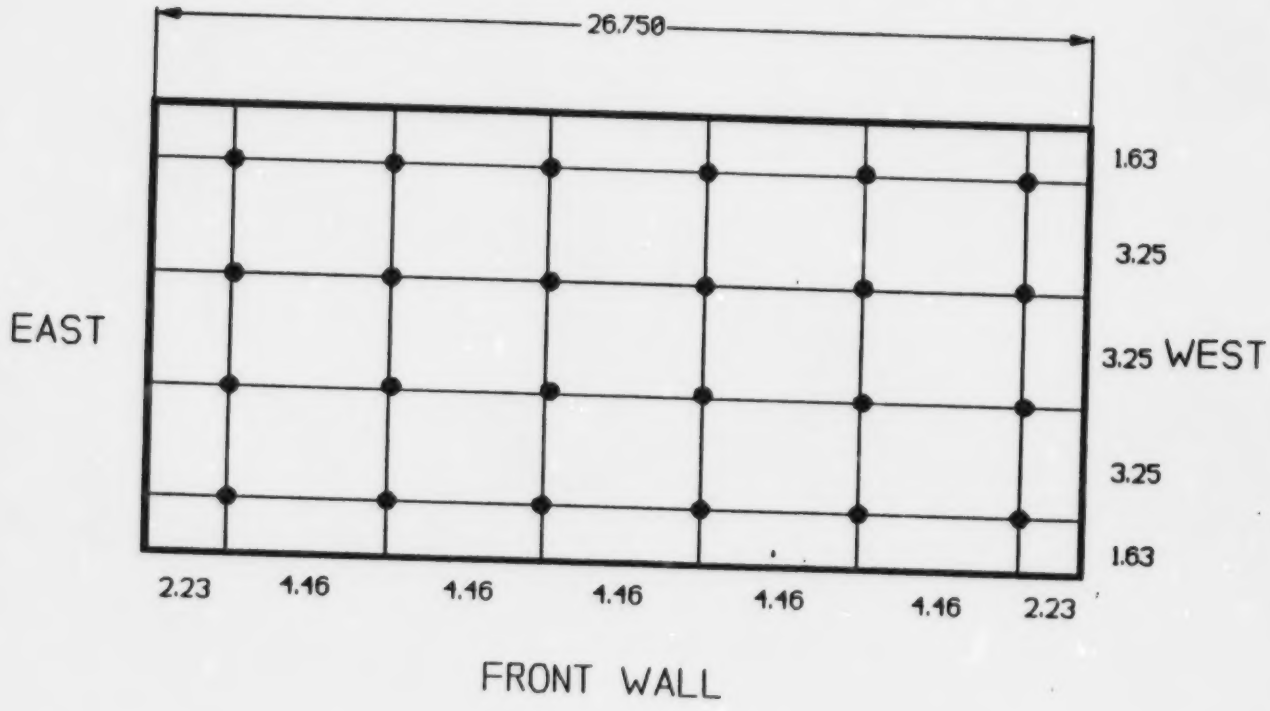


Figure C-4. Dispersion Measurements Grid Points

Table C-1. Dispersion Data for Full Load Injection with eight 3.75-in Jets and 5 % Transport Air

CONFIGURATION: FULL LOAD, 5% TA
JET DIAMETER: 0.375 IN
NO. OF JETS: 8
JETS FLOWRATE: 23.37 SCFM
ELEVATION: 804334

DATE: 12-5-89
INITIALS: JDM

Cex = 330 PPM

		1	2	3	4	5	6
PPM		930	20	20	39	287.5	210
AREA	1	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
C/Cex		2.82	0.06	0.06	0.12	0.87	0.64
		540	260	39	10	302.5	620
	2	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.64	0.79	0.12	0.03	0.92	1.88
		640	287.5	85	20	60	1305
	3	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.94	0.87	0.26	0.06	0.18	3.95
		410	375	310	20	20	425
	4	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.24	1.14	0.94	0.06	0.06	1.29

COV 1.06

Table C-2. Dispersion for Full Load Injection with Six 5.0 in Jets and 4 % Transport Air

CONFIGURATION: FULL LOAD, 4% TA
JET DIAMETER: 0.5 IN
NO. OF JETS: 6 @ -30 DEGREES
JETS FLOWRATE: 19.27 SCFM
ELEVATION: 804334

DATE: 12-7-89
INITIALS: JDM

Cex = 350 PPM

		1	2	3	4	5	6
PPM		237.5	367.5	270	287.5	740	445
AREA	1	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
C/Cex		0.68	1.05	0.77	0.82	2.11	1.27
		395	585	230	180	760	245
	2	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.13	1.67	0.66	0.51	2.17	0.70
		202.5	920	245	187.5	760	85
	3	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.58	2.63	0.70	0.54	2.17	0.24
		39	890	585	337.5	675	39
	4	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.11	2.54	1.67	0.96	1.93	0.11

COV 0.65

Table C-3. Dispersion Data for Full Load Injection with six 5.0 in Jets and 5 % Transport Air

CONFIGURATION: FULL LOAD, 5% TA
JET DIAMETER: 0.5 IN
NO. OF JETS: 6 @ -30 DEGREES
JETS FLOWRATE: 23.37 SCFM
ELEVATION: 804334

DATE: 12-5-89
INITIALS: JDM

Cex = 330 PPM

		1	2	3	4	5	6
PPM		77.5	252.5	330	410	715	245
AREA	1	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
C/Cex		0.23	0.77	1.00	1.24	2.17	0.74
		122.5	445	330	320	730	157.5
	2	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.37	1.35	1.00	0.97	2.21	0.48
		115	640	417.5	320	515	70
	3	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.35	1.94	1.27	0.97	1.56	0.21
		39	595	515	410	310	85
	4	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.12	1.80	1.56	1.24	0.94	0.26

COV 0.59

Table C-4. Dispersion Data for Full Load Injection with eight 5.0-in Jets and 5 % Transport Air

CONFIGURATION: FULL LOAD, 5% TA
JET DIAMETER: 0.5 IN
NO. OF JETS: 8
JETS FLOWRATE: 23.37 SCFM
ELEVATION: 807547

DATE: 12-5-89
INITIALS: JDM

Cex = 340 PPM

		1	2	3	4	5	6
PPM		115	685	39	20	230	640
AREA	1	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
C/Cex		0.34	2.01	0.11	0.06	0.68	1.88
		367.5	780	20	20	495	675
	2	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.08	2.29	0.06	0.06	1.46	1.99
		605	910	10	10	550	1047.5
	3	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.78	2.68	0.03	0.03	1.62	3.08
		280	695	10	20	180	410
	4	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.82	2.04	0.03	0.06	0.53	1.21

COV 0.88

Table C-5. Dispersion Data for Full Load Injection with Thirty-eight 2.5-in Jets

CONFIGURATION: FULL LOAD, 4% TA
JET DIAMETER: 0.25 IN
NO. OF JETS: LANCE, 38
JET FLOWRATE: 19.27 SCFM
ELEVATION: 807547

DATE: 12-7-89
INITIALS: JDM

Cex = 356.3 PPM

		1	2	3	4	5	6
PPM		252.5	195	585	750	820	515
AREA	1	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
C/Cex		0.71	0.55	1.64	2.10	2.30	1.45
		345	180	395	577.5	435	425
	2	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.97	0.51	1.11	1.62	1.22	1.19
		480	375	630	890	660	345
	3	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		1.35	1.05	1.77	2.50	1.85	0.97
		20	60	620	790	237.5	100
	4	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.06	0.17	1.74	2.22	0.67	0.28

COV 0.54

	1.97	1.88	1.35	1.67	1.61	0.30
4	10 0.1006 0.03	39 0.1006 0.12	70 0.1006 0.21	195 0.1006 0.59	287.5 0.1006 0.87	10 0.1006 0.03

COV 0.77

		1	2	3	4	5	6
PPM AREA C/Cex	1	77.5 0.1006 0.23	530 0.1006 1.61	385 0.1006 1.17	675 0.1006 2.05	595 0.1006 1.80	122.5 0.1006 0.37
	2	245 0.1006 0.74	585 0.1006 1.77	375 0.1006 1.14	750 0.1006 2.27	675 0.1006 2.05	165 0.1006 0.50
	3	310 0.1006 0.94	522.5 0.1006 1.58	460 0.1006 1.39	295 0.1006 0.89	530 0.1006 1.61	230 0.1006 0.70
	4	10 0.1006 0.03	50 0.1006 0.15	195 0.1006 0.59	360 0.1006 1.09	445 0.1006 1.35	70 0.1006 0.21

COV 0.59

Table C-8. Dispersion Data for Low Load Injection with eight 3.75 in Jets and 3 % Transport Air

CONFIGURATION: LOW LOAD, 3% TA
JET DIAMETER: 0.375 IN
NO. OF JETS: 8
JETS FLOWRATE: 15.17 SCFM
ELEVATION: 800790

DATE: 12-8-89
INITIALS: JDM

Cex = 330 PPM

		1	2	3	4	5	6
PPM		85	460	515	585	685	480
AREA	1	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
C/Cex		0.26	1.39	1.56	1.77	2.08	1.45
		130	445	410	675	640	612.5
	2	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.39	1.35	1.24	2.05	1.94	1.86
		165	435	530	570	435	210
	3	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.50	1.32	1.61	1.73	1.32	0.64
		70	187.5	425	550	260	29.5
	4	0.1006	0.1006	0.1006	0.1006	0.1006	0.1006
		0.21	0.57	1.29	1.67	0.79	0.09

COV 0.50

APPENDIX C
55 Pages

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE #. 33856
DATE : NOVEMBER 5, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-10-30

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
9:00 - 11:00	A.R.	39.93	24.21	14.07	21.80	2977
	A.D.	9.07	36.64	21.29	33.00	4506
	D.B.	----	40.29	23.41	36.29	4955
11:00 - 13:00	A.R.	39.84	25.01	13.35	21.80	3011
	A.D.	9.62	37.67	20.06	32.75	4524
	D.B.	----	41.67	22.20	36.24	5006
13:00 - 15:00	A.R.	38.50	25.58	13.31	22.61	3107
	A.D.	10.07	37.41	19.46	33.06	4544
	D.B.	----	41.60	21.64	36.76	5053
15:00 - 17:00	A.R.	38.04	26.38	12.20	23.38	3226
	A.D.	10.64	38.05	17.59	33.72	4653
	D.B.	----	42.58	19.68	37.74	5207

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 06 1990
CHIEF CHEMIST

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629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33856
DATE : NOVEMBER 5, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-10-30

ULTIMATE ANALYSIS, AIR DRIED

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
9:00 - 11:00	9.07	49.31	4.66	0.59	21.29	0.90	14.18
11:00 - 13:00	9.62	48.97	4.51	0.64	20.08	0.84	14.36
13:00 - 15:00	10.07	50.54	4.61	0.58	19.46	0.79	13.95
15:00 - 17:00	10.64	51.63	4.24	0.62	17.59	0.78	14.50

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 06 1990
CHIEF CHEMIST

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

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NOV 07 1990
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TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33 [illegible]
DATE : NOVEMBER 6, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-10-31

TIME		BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:0[illegible]	- 10:00	A.R.	37.75	25.60	13.32	23.33	3210
		A.D.	8.32	37.70	19.62	34.36	4728
		D.B.	----	41.12	21.40	37.48	5157
10:00	- 12:00	A.R.	37.80	25.20	13.57	23.44	3154
		A.D.	8.81	36.94	19.89	34.36	4667
		D.B.	----	40.51	21.81	37.68	5118
12:00	- 14:00	A.R.	38.03	24.86	13.81	23.31	3132
		A.D.	9.37	36.35	20.19	34.09	4580
		D.B.	----	40.11	22.28	37.61	5054
14:00	- 16:00	A.R.	38.37	25.43	12.77	23.43	3201
		A.D.	9.88	37.18	18.68	34.26	4681
		D.B.	----	41.26	20.73	38.02	5194
16:00	- 18:00	A.R.	38.43	26.06	12.48	23.04	3192
		A.D.	8.95	38.53	18.45	34.07	4720
		D.B.	----	42.32	20.26	37.42	5184
18:00	- 20:00	A.R.	37.87	25.66	13.65	22.82	3125
		A.D.	9.40	37.42	19.91	33.28	4557
		D.B.	----	41.30	21.97	36.73	5030

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629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : W.A.GARNER MITCHELL
COAL ANALYSIS : LIFAC TEST

FILE # : 33857
DATE : NOVEMBER 6, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-10-31

ULTIMATE ANALYSIS, AIR DRIED

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	8.32	51.79	3.88	0.61	19.62	1.13	14.65
10:00 - 12:00	8.81	50.98	3.91	0.64	19.89	1.03	14.74
12:00 - 14:00	9.37	50.55	3.70	0.59	20.19	1.08	14.52
14:00 - 16:00	9.88	51.40	4.23	0.60	18.68	0.94	14.27
16:00 - 18:00	8.95	52.53	4.45	0.67	18.45	0.87	14.08
18:00 - 20:00	9.40	50.16	3.87	0.56	19.91	0.84	15.27

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
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REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-01

TIME:		BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00	- 10:00	A.R.	38.00	24.56	14.14	23.30	3179
		A.D.	5.78	37.32	21.49	35.41	4831
		D.B.	----	39.61	22.81	37.58	5127
10:00	- 12:00	A.R.	37.60	24.93	13.97	23.50	3199
		A.D.	4.84	38.02	21.31	35.83	4878
		D.B	----	39.95	22.39	37.65	5126
12:00	- 14:00	A.R.	37.85	24.86	13.70	23.59	3211
		A.D.	8.82	36.47	20.10	34.61	4711
		D.B.	----	40.00	22.04	37.96	5167
14:00	- 16:00	A.R.	37.43	25.22	13.60	23.75	3235
		A.D.	5.69	38.01	20.50	35.80	4876
		D.B.	----	40.30	21.74	37.96	5170
16:00	- 18:00	A.R.	37.98	24.94	13.46	23.62	3190
		A.D.	4.01	38.60	20.83	36.56	4937
		D.B.	----	40.21	21.70	38.09	5143
18:00	- 20:00	A.R.	32.36	27.10	14.67	25.87	3466
		A.D	3.43	38.69	20.95	36.93	4949
		D.B	----	40.06	21.69	38.24	5125

COAL ANALYSIS : LIFAC TEST

REPORT BY : ARNO HOOGVELD

P.O.# P91 369 023

SAMPLING DATE : 90-11-01

---ULTIMATE ANALYSIS, AIR DRIED---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	5.78	51.47	3.92	0.59	21.49	1.25	15.50
10:00 - 12:00	4.84	52.14	3.07	0.61	21.31	1.17	16.86
12:00 - 14:00	8.82	49.80	3.54	0.57	20.10	1.03	16.14
14:00 - 16:00	5.69	52.27	3.66	0.60	20.50	1.06	16.22
16:00 - 18:00	4.01	53.23	3.30	0.66	20.83	0.96	17.01
18:00 - 20:00	3.43	53.47	3.59	0.63	20.95	0.96	16.97

NOTE : Hydrogen and oxygen do not include H and O from sample moisture
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33870
DATE : NOVEMBER 12, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-05

--- ULTIMATE ANALYSIS, AIR DRIED ---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	5.65	51.36	4.20	0.58	19.82	0.94	17.45
10:00 - 12:00	3.77	53.35	3.42	0.58	20.13	0.97	17.78
12:00 - 14:00	5.23	53.67	3.56	0.62	18.63	0.85	[illegible]
14:00 - 16:00	5.02	53.85	3.51	0.60	18.38	0.90	17.74
16:00 - 18:00	4.43	54.33	3.75	0.59	18.34	[illegible]	17.66
18:00 - 20:00	6.17	51.74	4.00	0.54	19.64	1.00	16.91

NOTE : Hydrogen and oxygen do not include H and O from sample moisture
Value of oxygen by difference

SASKPOWER TECHNICAL SERVICES & RESEARCH
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PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-05

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	38.15	25.26	12.99	23.59	3175
	A.D.	5.65	38.54	19.82	35.99	4843
	D.B	----	40.85	21.01	38.15	5133
10:00 - 12:00	A.R.	37.69	25.29	13.03	23.98	3217
	A.D.	3.77	39.06	20.13	37.04	4969
	D.B.	----	40.59	20.92	38.49	5165
12:00 - 14:00	A.R.	38.01	25.28	12.19	24.52	3241
	A.D.	5.23	38.65	18.63	37.49	4955
	D.B.	----	40.78	19.66	39.56	5228
14:00 - 16:00	A.R.	38.12	25.55	11.98	24.35	3232
	A.D.	5.02	39.22	18.38	37.38	4960
	D.B.	----	41.29	19.35	39.36	5222
16:00 - 18:00	A.R.	37.72	25.82	11.95	24.51	3277
	A.D.	4.43	39.62	18.34	37.61	5029
	D.B.	----	41.46	19.19	39.35	5262
18:00 - 20:00	A.R.	37.98	24.96	12.98	24.08	3193
	A.D.	6.17	37.76	19.64	36.43	4830
	D.B.	----	40.24	20.93	38.83	5149

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 14 1990
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P.O.# P91 359 023

SAMPLING DATE : 90-11-05/06 05/06

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
22:00 - 22:00	A.R.	38.25	25.63	11.54	24.58	3298
	A.D.	10.77	37.04	16.68	35.51	4766
	D.B.	----	41.51	18.69	39.80	5341
22:00 - 24:00	A.R.	37.54	25.52	12.94	24.00	3238
	A.D.	8.14	37.53	19.03	35.30	4759
	D.B.	----	40.86	20.72	38.43	5181
0:00 - 2:00	A.R.	38.30	25.10	13.01	23.59	3173
	A.D.	7.10	37.79	19.59	35.52	4778
	D.B.	----	40.68	21.09	38.23	5143
2:00 - 4:00	A.R.	38.11	25.51	12.97	23.41	3170
	A.D.	7.45	38.14	19.40	35.01	4740
	D.B.	----	41.21	20.96	37.83	5122
4:00 - 6:00	A.R.	38.08	25.68	12.28	23.97	3256
	A.D.	5.47	39.20	18.74	36.59	4971
	D.B.	----	41.47	19.82	38.71	5259
6:00 - 8:00	A.R.	38.32	25.27	12.43	23.98	3204
	A.D.	4.82	39.00	19.18	37.00	4944
	D.B.	----	40.97	20.15	38.87	5194

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NOV 14 1990
CHIEF CHEMIST

COAL ANALYSIS : LIFAC TEST

REPORT BY : ANNOTATED

PAGE : 4

P.O.# P91 359 023

SAMPLING DATE : 90-11-05/06 05/06

— ULTIMATE ANALYSIS , AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 – 22:00	10.77	51.73	3.78	0.58	16.58	0.92	15.64
22:00 – 24:00	8.14	51.47	3.18	0.58	19.03	1.06	16.55
0:00 – 2:00	7.10	51.39	3.47	0.58	19.59	1.15	16.74
2:00 – 4:00	7.45	51.78	3.56	0.58	19.40	1.06	16.20
4:00 – 6:00	5.47	53.27	3.80	0.59	18.74	0.97	17.16
6:00 – 8:00	4.82	53.36	3.83	0.58	19.18	1.07	17.18

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
NOV 14 1990
CHIEF CHEMIST

06

SAMPLING DATE : 90-11-13

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	38.14	24.82	12.57	24.47	3182
	A.D.	6.70	37.44	18.96	36.90	4799
	D.B.	----	40.13	20.32	39.55	5144
10:00 - 12:00	A.R.	38.54	24.42	13.02	24.03	3102
	A.D.	6.34	37.21	19.84	36.61	4727
	D.B.	----	39.73	21.18	39.09	5047
12:00 - 14:00	A.R.	38.40	24.62	12.69	24.28	3151
	A.D.	5.58	37.75	19.46	37.23	4831
	D.B.	----	39.97	20.61	39.42	5116
14:00 - 16:00	A.R.	38.33	24.85	12.55	24.27	3193
	A.D.	5.85	37.94	19.16	37.05	4876
	D.B.	----	40.30	20.35	39.35	5178
16:00 - 18:00	A.R.	38.46	24.42	12.80	24.31	3183
	A.D.	6.71	37.02	19.41	36.86	4825
	D.B.	----	39.68	20.81	39.51	5172
18:00 - 20:00	A.R.	38.12	24.63	12.58	24.66	3216
	A.D.	7.50	36.82	18.81	36.87	4808
	D.B.	----	39.81	20.34	39.86	5198

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 14 1990
CHIEF CHEMIST

COAL ANALYSIS : LIFAC TEST

P.O.# P91 359 023

SAMPLING DATE : 90-11-08

--ULTIMATE ANALYSIS, AIR DRIED--

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	6.70	51.34	4.14	0.68	18.98	0.98	17.22
10:00 - 12:00	6.34	51.43	3.98	0.68	19.84	1.15	16.58
12:00 - 14:00	5.56	52.63	3.16	0.72	19.46	0.99	17.48
14:00 - 16:00	5.85	52.38	3.29	0.68	19.16	0.98	17.66
16:00 - 18:00	6.71	52.04	3.69	0.63	19.41	0.99	16.53
18:00 - 20:00	7.50	51.63	3.49	0.64	18.81	1.02	16.91

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 14 1990
CHIEF CHEMIST

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33874
DATE : NOVEMBER 14, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-[illegible] 06/07

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	38.13	25.01	12.50	24.36	3247
	A.D.	6.03	37.98	18.99	37.00	4932
	D.B.	----	40.42	20.21	39.37	5248
22:00 - 24:00	A.R.	38.36	24.60	12.74	24.30	3197
	A.D.	4.42	38.14	19.76	37.68	4958
	D.B.	----	39.90	20.67	39.42	5187
0:00 - 2:00	A.R.	37.84	24.92	12.50	24.64	3202
	A.D.	10.68	36.87	17.98	35.46	4609
	D.B.	----	40.16	20.14	39.70	5160
2:00 - 4:00	A.R.	38.14	24.79	12.83	24.24	3182
	A.D.	9.79	36.16	18.71	35.35	4655
	D.B.	----	40.08	20.74	39.18	5160
4:00 - 6:00	A.R.	38.04	25.25	12.87	23.85	3190
	A.D.	8.61	37.24	18.98	35.17	4705
	D.B.	----	40.75	20.77	38.48	5148
6:00 - 8:00	A.R.	38.33	25.01	12.91	23.76	3175
	A.D.	8.18	37.23	19.22	35.37	4727
	D.B.	----	40.55	20.93	38.52	5148

SASKPOWER TECHNICAL SERVICES & RESEARCH
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629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

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NOV 2 0 1990

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33876
DATE : NOVEMBER 14, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-07

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	38.17	24.85	13.26	23.72	3164
	A.D.	4.78	38.27	20.42	36.53	4872
	D.B.	----	40.19	21.45	38.36	5117
10:00 - 12:00	A.R.	38.35	24.99	12.05	24.62	3227
	A.D.	5.23	38.41	18.52	37.84	4960
	D.B.	----	40.53	19.54	39.93	5234
12:00 - 14:00	A.R.	39.82	24.63	11.90	23.65	3178
	A.D.	7.30	37.94	18.33	36.43	4896
	D.B.	----	40.93	19.77	39.30	5282
14:00 - 16:00	A.R.	38.64	24.55	12.67	24.13	3191
	A.D.	5.73	37.72	19.47	37.08	4903
	D.B.	----	40.01	20.65	39.33	5201
16:00 - 18:00	A.R.	38.32	25.04	12.39	24.26	3228
	A.D.	5.59	38.32	18.96	37.13	4941
	D.B.	----	40.59	20.08	39.33	5234
18:00 - 20:00	A.R.	38.19	25.01	12.61	24.19	3238
	A.D.	7.88	37.27	18.79	36.06	4826
	D.B.	----	40.46	20.40	39.14	5239

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33876
DATE : NOVEMBER 14, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 2

P.O.# P91 359 023

SAMPLING DATE : 90-11-07

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	4.78	52.01	3.61	0.72	20.42	0.92	17.54
10:00 - 12:00	5.23	53.42	4.06	0.70	18.52	0.92	17.15
12:00 - 14:00	7.30	52.59	3.01	0.68	18.33	1.03	17.06
14:00 - 16:00	5.73	52.04	3.11	0.70	19.47	1.11	17.84
16:00 - 18:00	5.59	52.48	3.70	0.65	18.96	1.02	17.60
18:00 - 20:00	7.88	51.06	4.30	0.67	18.79	1.16	16.14

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

PAGE : 3

FILE # : 33876
DATE : NOVEMBER 14, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-07/08

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	38.63	25.08	11.93	24.36	3245
	A.D.	7.00	38.00	18.08	36.92	4917
	D.B.	----	40.86	19.44	39.70	5287
22:00 - 24:00	A.R.	38.59	25.28	11.52	24.60	3268
	A.D.	6.23	38.61	17.59	37.57	4990
	D.B.	----	41.18	18.76	40.07	5322
0:00 - 2:00	A.R.	38.35	25.31	12.36	23.98	3218
	A.D.	7.74	37.88	18.49	35.89	4815
	D.B.	----	41.06	20.04	38.90	5219
2:00 - 4:00	A.R.	38.41	25.17	12.10	24.32	3250
	A.D.	6.67	38.14	18.33	36.86	4925
	D.B.	----	40.87	19.64	39.49	5277
4:00 - 6:00	A.R.	38.57	25.29	12.06	24.07	3239
	A.D.	5.87	38.76	18.48	36.89	4963
	D.B.	----	41.18	19.63	39.19	5272
6:00 - 8:00	A.R.	38.50	25.25	11.93	24.32	3258
	A.D.	5.95	38.61	18.25	37.19	4983
	D.B.	----	41.05	19.40	39.54	5298

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33876
DATE : NOVEMBER 14, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-07/08

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	7.00	52.53	3.44	0.65	18.08	0.95	17.35
22:00 - 24:00	6.23	53.29	3.60	0.71	17.59	0.95	17.63
0:00 - 2:00	7.74	50.99	3.62	0.70	18.49	1.01	17.45
2:00 - 4:00	6.67	52.93	3.61	0.68	18.33	1.04	16.74
4:00 - 6:00	5.87	53.31	3.95	0.68	18.48	1.08	16.63
6:00 - 8:00	5.95	53.46	4.02	0.67	18.25	0.89	16.76

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

P.O.# P91 359 023

SAMPLING DATE : 90-11-[illegible]

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	37.51	25.84	12.56	24.08	3256
	A.D.	8.99	37.64	18.30	35.07	4742
	D.B.	----	41.36	20.11	38.53	5210
10:00 - 12:00	A.R.	38.20	25.52	12.71	23.58	3155
	A.D.	7.53	38.18	19.01	35.28	4721
	D.B.	----	41.29	20.56	38.15	5105
12:00 - 14:00	A.R.	37.90	25.84	11.67	24.59	3176
	A.D.	7.82	38.36	17.32	36.50	4715
	D.B.	----	41.61	18.79	39.60	5115
14:00 - 16:00	A.R.	38.11	25.46	12.12	24.31	3273
	A.D.	6.48	38.47	18.31	36.74	4945
	D.B.	----	41.14	19.58	39.29	5288
16:00 - 18:00	A.R.	38.77	25.46	12.23	23.55	3214
	A.D.	12.03	38.57	17.57	33.83	4617
	D.B.	----	41.57	19.97	38.46	5248
18:00 - 20:00	A.R.	38.08	25.34	12.61	23.98	3256
	A.D.	7.08	38.02	18.92	35.98	4886
	D.B.	----	40.92	20.38	38.72	5258

SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
NOV 20 1990
CHIEF CHEMIST

ATTN : S. VAN DER HEIJDEN, IS&H
COAL ANALYSIS : LIFAC TEST

DATE : NOVEMBER 16, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 2

P.O.# P91 359 023

SAMPLING DATE : 90-11-08

— ULTIMATE ANALYSIS , AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	8.99	50.30	3.86	0.65	18.30	0.76	17.14
10:00 - 12:00	7.53	50.61	3.14	0.68	19.01	1.03	18.00
12:00 - 14:00	7.82	52.70	3.28	0.68	17.32	0.94	17.28
14:00 - 16:00	6.48	52.89	4.17	0.67	18.31	0.89	16.59
16:00 - 18:00	12.03	49.89	3.63	0.63	17.57	0.87	15.38
18:00 - 20:00	7.08	50.95	3.24	0.65	18.92	0.86	18.30

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 20 1990
CHIEF CHEMIST

P.O.# P91 359 023

SAMPLING DATE: 90-11-20/09

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	38.43	25.24	13.03	23.30	3180
	A.D.	9.24	37.21	19.21	34.34	4687
	D.B.	----	41.00	21.17	37.84	5164
22:00 - 24:00	A.R.	38.93	25.15	12.37	23.56	3186
	A.D.	8.00	37.88	18.63	35.49	4799
	D.B.	----	41.17	20.25	38.58	5216
0:00 - 2:00	A.R.	38.17	25.57	12.01	24.25	3238
	A.D.	6.85	38.62	18.09	36.54	4878
	D.B.	----	41.35	19.42	39.23	5237
2:00 - 4:00	A.R.	38.47	25.16	12.28	24.09	3175
	A.D.	9.04	37.19	18.16	35.61	4694
	D.B.	----	40.89	19.96	39.15	5161
4:00 - 6:00	A.R.	38.84	24.82	11.96	24.38	3218
	A.D.	8.80	37.01	17.84	36.35	4799
	D.B.	----	40.58	19.56	39.86	5262
6:00 - 8:00	A.R.	39.02	24.75	12.69	23.55	3167
	A.D.	7.96	37.35	19.15	35.54	4780
	D.B.	----	40.58	20.81	38.61	5193

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 20 1990
CHIEF CHEMIST

LORING LABORATORIES
29 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33881
DATE : NOVEMBER 15, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 369 023

SAMPLING DATE: 90-11-08/09

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	9.24	49.51	3.23	0.68	19.21	0.84	17.29
22:00 - 24:00	8.00	51.47	5.57	0.68	18.63	0.83	14.82
0:00 - 2:00	8.85	52.87	4.58	0.67	18.09	0.84	16.10
2:00 - 4:00	9.04	51.59	3.40	0.68	18.16	0.91	16.22
4:00 - 6:00	8.80	51.85	3.60	0.67	17.84	0.80	16.44
6:00 - 8:00	7.96	51.47	4.15	0.67	19.15	1.19	15.41

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
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NOV 20 1990
CHIEF CHEMIST

P.O.# P91 388 023

SAMPLING DATES : NOVEMBER 13/14/15, 1990

	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
10 - 12:00	A.R.	38.09	25.67	11.58	24.66	3321
/ 13	A.D.	6.68	38.70	17.45	37.17	5006
	D.B.	----	41.47	18.70	39.83	5364
0 - 8:00	A.R.	38.05	24.48	12.88	24.59	3172
/ 14	A.D.	7.08	36.72	19.32	36.88	4758
	D.B.	----	39.52	20.79	39.69	5121
0 - 10:00	A.R.	38.00	24.61	12.47	24.92	3251
V 15	A.D.	9.11	36.08	18.28	36.53	4765
	D.B.	----	39.70	20.11	40.19	5243

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 34046
DATE : JANUARY 30, 1991
REPORT BY : ARNO HOOGVELD

PAGE : 4

P.O.# P91 369 023

SAMPLING DATES : NOVEMBER 13/14/15, 1990

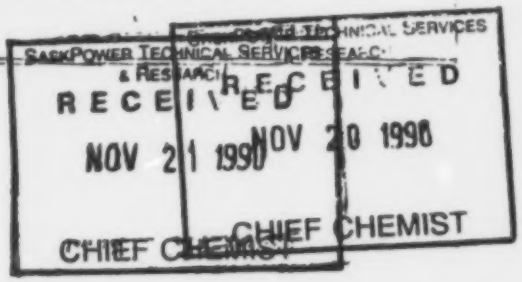
ULTIMATE ANALYSIS, AIR DRIED ---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
10:00 - 12:00 NOV 13	6.68	54.29	3.88	0.81	17.45	0.94	15.95
6:00 - 8:00 NOV 14	7.08	50.64	3.40	0.70	19.32	1.09	17.87
8:00 - 10:00 NOV 15	9.11	51.13	3.67	0.72	18.28	0.99	16.10

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SAMPLING DATE : 90-11-19

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 – 10:00	A.R.	37.20	25.80	12.10	24.90	3346
	A.D.	7.02	38.19	17.92	36.87	4953
	D.B.	----	41.07	19.27	39.65	5327
10:00 – 12:00	A.R.	37.04	26.07	11.46	25.44	3374
	A.D.	6.48	38.72	17.02	37.78	5011
	D.B.	----	41.40	18.20	40.40	5358
12:00 – 14:00	A.R.	37.16	25.39	12.20	25.24	3324
	A.D.	6.81	37.66	18.10	37.44	4930
	D.B.	----	40.40	19.42	40.18	5290
14:00 – 16:00	A.R.	37.20	24.97	12.86	24.97	3301
	A.D.	7.69	36.62	18.87	36.62	4342
	D.B.	----	39.76	20.49	39.76	5257
16:00 – 18:00	A.R.	36.80	24.95	13.30	24.95	3291
	A.D.	7.78	36.41	19.40	36.41	4802
	D.B.	----	39.48	21.04	39.48	5207
18:00 – 20:00	A.R.	36.77	24.82	14.37	24.05	3198
	A.D.	7.61	36.26	20.99	35.14	4673
	D.B.	----	39.25	22.72	38.03	5058



P.O.# P91 359 023

SAMPLING DATE : 90-11-13

---ULTIMATE ANALYSIS, AIR DRIED---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	7.02	53.41	4.77	0.65	17.92	1.09	15.14
10:00 - 12:00	6.48	54.26	4.49	0.85	17.02	0.90	16.00
12:00 - 14:00	6.81	53.36	3.99	0.64	18.10	0.92	16.18
14:00 - 16:00	7.89	52.50	3.88	0.73	18.87	1.07	15.06
16:00 - 18:00	7.78	51.78	4.11	0.63	19.40	1.08	15.22
18:00 - 20:00	7.61	50.21	3.94	0.63	20.99	1.02	15.60

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
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CHIEF CHEMIST

P.O.# P81 388 023

SAMPLING DATE : 90-11-13/14

--- ULTIMATE ANALYSIS , AIR DRIED

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	8.13	48.80	4.14	0.68	19.78	0.94	17.53
22:00 - 24:00	7.13	49.61	4.55	0.69	20.05	1.07	17.00
0:00 - 2:00	7.82	52.98	3.73	0.69	18.01	0.95	15.82
2:00 - 4:00	8.27	51.03	3.86	0.68	18.51	0.98	16.67
4:00 - 6:00	6.92	51.94	3.86	0.75	18.78	0.94	16.81
6:00 - 8:00	6.07	50.04	3.79	0.69	19.84	1.18	18.29

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
NOV 21 1990
CHIEF CHEMIST

P.O.# P91 359 023

SAMPLING DATE : 90-11-13/14

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	37.00	25.24	13.56	24.19	3267
	A.D.	8.13	36.81	19.78	42.18	4764
	D.B.	----	40.07	21.53	38.40	5186
22:00 - 24:00	A.R.	36.89	26.38	13.63	23.13	3289
	A.D.	7.13	38.79	20.05	34.03	4840
	D.B.	----	41.77	21.59	36.64	5212
0:00 - 2:00	A.R.	37.09	25.44	12.29	25.18	3312
	A.D.	7.82	37.28	18.01	36.89	4852
	D.B.	----	40.44	19.54	40.02	5264
2:00 - 4:00	A.R.	37.09	25.27	12.69	24.94	3290
	A.D.	8.27	38.85	18.51	36.37	4797
	D.B.	----	40.17	20.18	39.65	5229
4:00 - 6:00	A.R.	37.02	24.81	12.71	25.47	3282
	A.D.	6.92	36.66	18.78	37.84	4851
	D.B.	----	39.39	20.18	40.44	5212
6:00 - 8:00	A.R.	37.04	24.56	13.37	25.04	3252
	A.D.	6.07	36.64	19.94	37.35	4852
	D.B.	----	39.01	21.23	39.76	5166

SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
NOV 21 1990
CHIEF CHEMIST

File AD 38-8

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33894
DATE : NOVEMBER 21, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

PRPS
NOV 27 1990

SAMPLING DATE : 90-11-14

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	36.60	25.07	13.02	25.30	3264
	A.D.	7.36	36.64	19.03	36.97	4770
	D.B.	----	39.55	20.54	39.91	5149
10:00 - 12:00	A.R.	36.97	24.68	13.26	25.09	3261
	A.D.	6.71	36.53	19.63	37.13	4827
	D.B.	----	39.16	21.04	39.80	5174
12:00 - 14:00	A.R.	37.14	25.00	12.49	25.37	3292
	A.D.	7.83	36.66	18.31	37.20	4827
	D.B.	----	39.77	19.87	40.36	5237
14:00 - 16:00	A.R.	37.49	25.09	12.10	25.32	3274
	A.D.	6.05	37.71	18.18	38.06	4920
	D.B.	----	40.14	19.35	40.51	5237
16:00 - 18:00	A.R.	38.32	23.86	12.08	25.73	3253
	A.D.	6.93	36.01	18.23	38.83	4908
	D.B.	----	38.69	19.59	41.72	5273
18:00 - 20:00	A.R.	37.97	23.84	12.92	25.26	3260
	A.D.	7.07	35.72	19.36	37.85	4884
	D.B.	----	38.44	20.83	40.73	5256

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33894
DATE : NOVEMBER 21, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 2

P.O.# P91 359 023

PRPS
NOV 27 1990

SAMPLING DATE : 90-11-14

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 – 10:00	7.36	52.65	3.88	0.71	19.03	1.00	15.37
10:00 – 12:00	6.71	51.61	4.15	0.73	19.63	1.07	16.10
12:00 – 14:00	7.83	52.70	3.84	0.68	18.31	1.10	15.54
14:00 – 16:00	6.05	53.88	4.32	0.75	18.18	0.94	15.88
16:00 – 18:00	6.93	53.10	4.32	0.75	18.23	0.99	15.68
18:00 – 20:00	7.07	52.32	4.42	0.76	19.36	1.14	14.93

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33894
DATE : NOVEMBER 21, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 3

P.O.# P91 359 023

NOV 27 1990

SAMPLING DATE : 90-11-14/15

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	37.79	23.63	13.78	24.81	3193
	A.D.	5.70	35.81	20.89	37.60	4839
	D.B.	----	37.97	22.15	39.87	5131
22:00 - 24:00	A.R.	37.82	24.39	13.12	24.66	3213
	A.D.	7.07	36.46	19.61	36.86	4803
	D.B.	----	39.23	21.10	39.66	5168
0:00 - 2:00	A.R.	38.23	24.54	12.02	25.22	3271
	A.D.	6.50	37.14	18.19	38.17	4951
	D.B.	----	39.72	19.45	40.82	5295
2:00 - 4:00	A.R.	38.14	23.74	12.64	25.49	3221
	A.D.	6.10	36.03	19.18	38.69	4889
	D.B.	----	38.37	20.43	41.20	5207
4:00 - 6:00	A.R.	38.30	24.09	11.74	25.87	3288
	A.D.	6.16	36.63	17.86	39.35	5000
	D.B.	----	39.03	19.03	41.93	5328
6:00 - 8:00	A.R.	38.23	23.90	11.94	25.93	3275
	A.D.	6.70	36.10	18.04	39.16	4946
	D.B.	----	38.69	19.34	41.97	5301

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33894
DATE : NOVEMBER 21, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

P PS
NOV 27 1990

SAMPLING DATE : 90-11-14/15

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	5.70	51.60	4.75	0.67	20.89	1.11	15.28
22:00 - 24:00	7.07	51.93	4.49	0.68	19.61	1.01	15.21
0:00 - 2:00	6.50	54.19	4.31	0.74	18.19	0.96	15.11
2:00 - 4:00	6.10	53.37	4.61	0.74	19.18	1.10	14.89
4:00 - 6:00	6.16	54.50	4.45	0.77	17.86	0.96	15.30
6:00 - 8:00	6.70	53.56	4.11	0.68	18.04	0.95	15.96

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33895
DATE : NOVEMBER 22, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-15

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	37.51	24.43	12.61	25.44	3274
	A.D.	8.85	35.64	18.40	37.11	4775
	D.B.	----	39.10	20.19	40.71	5239
10:00 - 12:00	A.R.	38.08	24.41	11.69	25.81	3315
	A.D.	9.45	35.70	17.10	37.75	4847
	D.B.	----	39.43	18.88	41.69	5353
12:00 - 14:00	A.R.	37.38	24.16	12.50	25.95	3311
	A.D.	9.46	34.94	18.08	37.52	4787
	D.B.	----	38.59	19.97	41.44	5287
14:00 - 16:00	A.R.	38.23	24.02	12.04	25.72	3275
	A.D.	9.51	35.18	17.64	37.67	4797
	D.B.	----	38.88	19.49	41.63	5301
16:00 - 18:00	A.R.	37.06	24.64	12.42	25.88	3332
	A.D.	9.46	35.44	17.87	37.23	4793
	D.B.	----	39.14	19.74	41.12	5294
18:00 - 20:00	A.R.	38.14	23.74	12.55	25.58	3239
	A.D.	9.35	34.78	18.39	37.48	4746
	D.B.	----	38.37	20.29	41.35	5236

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33895
DATE : NOVEMBER 22, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-15

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	8.85	50.70	3.14	0.69	18.40	1.07	17.15
10:00 - 12:00	9.45	52.30	3.50	0.64	17.10	0.97	16.04
12:00 - 14:00	9.46	51.56	3.26	0.64	18.08	0.98	16.02
14:00 - 16:00	9.51	51.11	3.42	0.71	17.64	0.96	16.65
16:00 - 18:00	9.46	50.62	3.77	0.69	17.87	0.97	16.62
18:00 - 20:00	9.35	50.26	3.48	0.61	18.39	1.02	16.89

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33895
DATE : NOVEMBER 22, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 3

P.O.# P91 359 023

SAMPLING DATE : 90-11-15/16

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	36.97	24.22	12.65	26.16	3313
	A.D.	13.04	33.41	17.46	36.09	4571
	D.B.	----	38.42	20.08	41.50	5256
22:00 - 24:00	A.R.	37.58	24.08	12.52	25.82	3284
	A.D.	8.94	35.12	18.27	37.67	4790
	D.B.	----	38.57	20.06	41.37	5260
0:00 - 2:00	A.R.	37.44	23.99	12.82	25.75	3267
	A.D.	8.65	35.03	18.72	37.60	4770
	D.B.	----	38.35	20.49	41.16	5222
2:00 - 4:00	A.R.	37.50	24.87	11.69	25.93	3369
	A.D.	8.72	36.33	17.08	37.87	4921
	D.B.	----	39.80	18.71	41.49	5391
4:00 - 6:00	A.R.	37.24	23.94	12.99	25.83	3259
	A.D.	7.89	35.13	19.07	37.91	4783
	D.B.	----	38.14	20.70	41.16	5193
6:00 - 8:00	A.R.	37.69	23.93	12.73	25.65	3248
	A.D.	8.88	35.00	18.61	37.51	4749
	D.B.	----	38.41	20.42	41.17	5212
8:00 - 10:00	A.R.	37.88	24.33	13.18	24.60	3172
	A.D.	8.78	35.73	19.36	36.13	4658
	D.B.	----	39.17	21.22	39.61	5106

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TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33895
DATE : NOVEMBER 22, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 4

P.O.# P91 359 023

SAMPLING DATE : 90-11-15/16

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	13.04	48.64	3.54	0.57	17.46	0.98	15.77
22:00 - 24:00	8.94	50.84	3.79	0.65	18.27	1.09	16.42
0:00 - 2:00	8.65	50.91	3.60	0.60	18.72	1.15	16.37
2:00 - 4:00	8.72	52.34	3.52	0.67	17.08	0.92	16.75
4:00 - 6:00	7.89	51.24	3.40	0.69	19.07	1.09	16.62
6:00 - 8:00	8.88	50.77	4.01	0.68	18.61	1.09	15.96
8:00 - 10:00	8.78	50.31	4.04	0.65	19.36	1.13	15.73

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.
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SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
OCT 25 1990
CHIEF CHEMIST

TO : SASKPOWER
ATTN : W.A. GARNER MITCHELL
COAL ANALYSIS : LIFAC TEST

FILE # : 33804
DATE : OCTOBER 24, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O. # : 359 023

SAMPLING DATE : 90-10-16

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	37.93	25.25	13.58	23.24	3141
	A.D.	7.41	37.67	20.25	34.67	4685
	D.B.	----	40.68	21.87	37.44	5060
10:00 - 12:00	A.R.	38.07	25.89	13.08	22.97	3195
	A.D.	7.07	38.86	19.60	34.47	4794
	D.B.	----	41.82	21.09	37.09	5159
12:00 - 14:00	A.R.	37.51	26.05	13.43	23.01	3153
	A.D.	6.04	38.34	19.76	33.86	4639
	D.B.	----	41.69	21.49	36.82	5045
14:00 - 16:00	A.R.	37.16	25.95	13.34	23.54	3159
	A.D.	7.09	38.37	19.73	34.81	4670
	D.B.	----	41.30	21.24	37.47	5026
16:00 - 18:00	A.R.	37.17	26.16	13.50	23.17	3138
	A.D.	8.61	38.05	19.63	33.71	4564
	D.B.	----	41.63	21.48	36.89	4994
18:00 - 20:00	A.R.	37.10	25.99	13.63	23.27	3190
	A.D.	8.09	37.95	19.92	34.01	4661
	D.B.	----	41.32	21.67	37.00	5071

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CALGARY, ALBERTA.
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SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
OCT 25 1990
CHIEF CHEMIST

TO : SASKPOWER
ATTN : W.A. GARNER MITCHELL
COAL ANALYSIS : LIFAC TEST

FILE # : 33804
DATE : OCTOBER 24, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 2

P.O.# P91 359 023

SAMPLING DATE : 90-10-18

--- ULTIMATE ANALYSIS, AIR DRIED

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	7.41	50.66	4.03	0.62	20.25	0.89	16.14
10:00 - 12:00	7.07	51.10	4.36	0.62	19.60	0.92	16.34
12:00 - 14:00	8.04	50.25	4.15	0.60	19.76	0.76	16.44
14:00 - 16:00	7.09	50.94	4.13	0.64	19.73	0.75	16.72
16:00 - 18:00	8.61	50.17	4.22	0.63	19.63	0.74	16.00
18:00 - 20:00	8.09	50.11	4.33	0.60	19.92	0.75	16.20

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

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SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
OCT 25 1990
CHIEF CHEMIST

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 3 3 8 1 0
DATE : OCTOBER 25, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P01 359 023

SAMPLING DATE ; 90-10-17

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	36.32	26.30	14.17	23.21	3170
	A.D.	7.12	38.36	20.67	33.85	4624
	D.B.	----	41.30	22.25	36.44	4978
10:00 - 12:00	A.R.	36.46	26.11	14.81	22.62	3140
	A.D.	8.36	37.66	21.36	32.62	4529
	D.B.	----	41.10	23.31	35.60	4942
12:00 - 14:00	A.R.	36.54	25.83	14.70	22.92	3132
	A.D.	7.86	37.51	21.35	33.28	4548
	D.B.	----	40.71	23.17	36.12	4936
14:00 - 16:00	A.R.	37.08	25.91	13.77	23.25	3152
	A.D.	7.19	38.21	20.31	34.29	4649
	D.B.	----	41.17	21.88	36.95	5009
16:00 - 18:00	A.R.	37.02	25.72	14.04	23.22	3185
	A.D.	7.56	37.75	20.61	34.08	4675
	D.B.	----	40.84	22.30	36.87	5057
18:00 - 20:00	A.R.	37.41	25.54	14.44	22.61	3151
	A.D.	7.71	37.66	21.29	33.34	4646
	D.B.	----	40.81	23.07	36.13	5034

18 20

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SASKPOWER TECHNICAL SERVICES & RESEARCH
RECEIVED
OCT 25 1990
CHIEF CHEMIST

TO : SASKPOWER
ATTN : W.A. GARNER MITCHELL
COAL ANALYSIS : LIFAC TEST

FILE # : 33810
DATE : OCTOBER 25, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-10-17

-- ULTIMATE ANALYSIS, AIR DRIED --

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	7.12	50.75	4.51	0.63	20.67	0.87	15.45
10:00 - 12:00	8.36	50.02	4.38	0.59	21.38	0.91	14.40
12:00 - 14:00	7.86	49.23	4.89	0.60	21.35	0.88	15.21
14:00 - 16:00	7.19	51.05	4.72	0.62	20.31	0.81	15.30
16:00 - 18:00	7.56	50.49	4.66	0.64	20.61	0.93	15.11
18:00 - 20:00	7.71	50.20	4.78	0.62	21.29	0.92	14.48

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

SAMPLING DATES : OCTOBER 17/18

	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
) – 14:00	A.R.	37.19	24.91	14.23	23.67	3150
17	A.D.	8.20	36.41	20.80	34.59	4604
	D.B.	----	39.66	22.66	37.68	5015
) – 16:00	A.R.	37.36	24.82	13.86	23.95	3164
17	A.D.	8.13	36.41	20.33	35.13	4641
	D.B.	----	39.63	22.13	38.24	5052
) – 12:00	A.R.	37.74	24.36	14.18	23.73	3167
18	A.D.	6.32	36.65	21.33	35.70	4766
	D.B.	----	39.12	22.77	38.11	5086
) – 18:00	A.R.	37.77	24.72	14.24	23.26	3104
18	A.D.	5.15	37.68	21.71	35.46	4731
	D.B.	----	39.73	22.89	37.39	4988

COAL ANALYSIS : LIFAC TEST

REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATES : OCTOBER 17/18

--- ULTIMATE ANALYSIS , AIR DRIED ---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
12:00 - 14:00 OCT 17	8.20	49.62	3.55	0.63	20.80	0.84	16.36
14:00 - 16:00 OCT 17	8.13	50.94	4.18	0.65	20.33	0.89	14.88
10:00 - 12:00 OCT 18	6.32	50.25	4.27	0.62	21.33	1.14	16.07
16:00 - 18:00 OCT 18	6.16	51.59	3.77	0.71	21.71	0.92	16.15

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E.
CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33816
DATE : OCTOBER 25, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-10-18

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	36.98	25.03	14.44	23.55	3187
	A.D.	3.85	38.19	22.03	35.93	4863
	D.B.	----	39.72	22.91	37.37	5058
10:00 - 12:00	A.R.	37.05	25.17	14.16	23.62	3223
	A.D.	3.72	38.49	21.66	36.13	4929
	D.B.	----	39.98	22.50	37.53	5119
12:00 - 14:00	A.R.	36.83	25.32	13.79	24.05	3246
	A.D.	3.83	38.55	21.00	36.62	4942
	D.B.	----	40.09	21.84	38.08	5139
14:00 - 16:00	A.R.	37.33	24.67	14.17	23.84	3157
	A.D.	4.09	37.75	21.68	36.48	4831
	D.B.	----	39.36	22.60	38.04	5037
16:00 - 18:00	A.R.	37.54	24.89	13.96	23.61	3138
	A.D.	4.00	38.25	21.46	36.29	4823
	D.B.	----	39.84	22.35	37.80	5024
18:00 - 20:00	A.R.	36.95	25.11	14.09	23.86	3182
	A.D.	4.01	38.22	21.45	36.32	4844
	D.B.	----	39.82	22.35	37.84	5046

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TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 3 3 8 1 6
DATE : OCTOBER 26, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-10-18

--- ULTIMATE ANALYSIS, AIR DRIED ---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	3.85	52.42	3.95	0.61	22.03	1.09	16.05
10:00 - 12:00	3.72	52.16	3.70	0.62	21.66	1.15	16.99
12:00 - 14:00	3.83	52.60	3.68	0.62	21.00	1.05	17.22
14:00 - 16:00	4.09	52.01	3.76	0.64	21.68	0.90	16.92
16:00 - 18:00	4.00	52.31	3.48	0.62	21.46	0.97	17.16
18:00 - 20:00	4.01	52.80	3.84	0.60	21.45	0.93	16.37

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

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TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

PRPS
DEC - 5 1990

FILE # : 33899
DATE : NOVEMBER 26, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-19

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
6:00 - 8:00	A.R.	37.44	25.02	12.58	24.95	3282
	A.D.	11.90	35.24	17.72	35.14	4622
	D.B.	----	40.00	20.11	39.89	5246
8:00 - 10:00	A.R.	37.84	25.13	12.63	24.41	3254
	A.D.	11.29	35.86	18.02	34.83	4644
	D.B.	----	40.42	20.31	39.26	5235
10:00 - 12:00	A.R.	37.70	24.42	12.90	24.98	3252
	A.D.	9.67	35.41	18.70	36.22	4715
	D.B.	----	39.20	20.70	40.10	5220
12:00 - 14:00	A.R.	37.34	24.66	13.29	24.71	3234
	A.D.	10.34	35.29	19.01	35.36	4628
	D.B.	----	39.36	21.20	39.44	5162
14:00 - 16:00	A.R.	37.16	24.84	12.80	25.20	3274
	A.D.	11.35	35.04	18.06	35.55	4618
	D.B.	----	39.53	20.37	40.10	5209
16:00 - 18:00	A.R.	37.45	24.60	12.26	25.70	3294
	A.D.	10.25	35.29	17.59	36.87	4726
	D.B.	----	39.32	19.60	41.08	5266

LORING LABORATORIES LTD.

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TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33899
DATE : NOVEMBER 26, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 2

P.O.# P91 359 023

SAMPLING DATE : 90-11-19

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
6:00 - 8:00	11.90	49.88	3.95	0.66	17.72	0.85	15.04
8:00 - 10:00	11.29	50.08	3.94	0.65	18.02	0.90	15.12
10:00 - 12:00	9.67	50.59	4.20	0.61	18.70	0.97	15.26
12:00 - 14:00	10.34	49.92	3.28	0.63	19.01	1.01	15.81
14:00 - 16:00	11.35	50.07	3.62	0.59	18.06	1.06	15.25
16:00 - 18:00	10.25	51.94	3.32	0.60	17.59	0.86	15.44

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33899
DATE : NOVEMBER 26, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 3

P.O.# P91 359 023

SAMPLING DATE : 90-11-19/20

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
18:00 - 20:00	A.R.	37.39	24.80	12.95	24.86	3279
	A.D.	10.04	35.63	18.61	35.72	4712
	D.B.	----	39.61	20.69	39.71	5238
20:00 - 22:00	A.R.	37.91	24.70	12.39	25.00	3308
	A.D.	9.20	36.12	18.12	36.56	4837
	D.B.	----	39.78	19.96	40.26	5327
22:00 - 24:00	A.R.	37.78	24.49	12.70	25.03	3259
	A.D.	10.25	35.32	18.32	36.11	4701
	D.B.	----	39.35	20.41	40.23	5238
0:00 - 2:00	A.R.	37.53	24.63	13.51	24.33	3233
	A.D.	11.26	34.99	19.19	34.56	4593
	D.B.	----	39.43	21.62	38.95	5176
2:00 - 4:00	A.R.	37.74	24.81	12.72	24.74	3254
	A.D.	10.80	35.54	18.22	35.44	4662
	D.B.	----	39.84	20.43	39.73	5226
4:00 - 6:00	A.R.	37.62	25.66	12.44	24.28	3266
	A.D.	9.74	37.13	18.00	35.13	4726
	D.B.	----	41.14	19.94	38.92	5236
6:00 - 8:00	A.R.	37.21	26.10	12.93	23.76	3277
	A.D.	10.78	37.09	18.37	33.76	4657
	D.B.	----	41.57	20.59	37.84	5220

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33899
DATE : NOVEMBER 26, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 4

P.O.# P91 359 023

SAMPLING DATE : 90-11-19/20

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
18:00 - 20:00	10.04	50.54	3.41	0.64	18.61	1.05	15.70
20:00 - 22:00	9.20	52.27	4.14	0.64	18.12	0.89	14.75
22:00 - 24:00	10.25	50.36	3.51	0.63	18.32	0.97	15.96
0:00 - 2:00	11.26	49.50	3.49	0.63	19.19	1.05	14.88
2:00 - 4:00	10.80	50.03	3.44	0.63	18.22	0.96	15.92
4:00 - 6:00	9.74	52.06	3.62	0.61	18.00	0.92	15.05
6:00 - 8:00	10.78	49.98	3.13	0.59	18.37	0.92	16.23

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

PRPS
DEC - 5 1990

FILE # : 33904
DATE : NOVEMBER 27, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-20

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	37.23	25.34	13.55	23.89	3276
	A.D.	10.41	36.16	19.34	34.09	4676
	D.B.	----	40.36	21.59	38.05	5219
10:00 - 12:00	A.R.	38.04	24.88	12.33	24.76	3259
	A.D.	10.93	35.76	17.72	35.59	4685
	D.B.	----	40.15	19.89	39.96	5260
12:00 - 14:00	A.R.	37.71	25.31	11.95	25.03	3295
	A.D.	10.85	36.22	17.11	35.82	4716
	D.B.	----	40.63	19.19	40.18	5290
14:00 - 16:00	A.R.	37.60	25.93	11.62	24.85	3365
	A.D.	10.93	37.01	16.59	35.47	4803
	D.B.	----	41.55	18.63	39.82	5392
16:00 - 18:00	A.R.	37.51	25.26	12.98	24.26	3263
	A.D.	9.34	36.64	18.83	35.19	4734
	D.B.	----	40.41	20.77	38.82	5222
18:00 - 20:00	A.R.	37.84	25.09	12.39	24.69	3258
	A.D.	10.69	36.04	17.80	35.47	4681
	D.B.	----	40.35	19.93	39.72	5241

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ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33904
DATE : NOVEMBER 27, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-20

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	10.41	49.02	4.01	0.56	19.34	1.13	15.53
10:00 - 12:00	10.93	50.29	3.53	0.62	17.72	0.87	16.04
12:00 - 14:00	10.85	50.49	3.62	0.62	17.11	0.82	16.48
14:00 - 16:00	10.93	51.65	3.91	0.62	16.59	0.77	15.53
16:00 - 18:00	9.34	50.83	3.47	0.60	18.83	0.92	16.01
18:00 - 20:00	10.69	49.71	3.61	0.60	17.80	0.92	16.67

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGAHY, ALBERTA.
TEL : (403) 274-2777 FAX : (403) 275-0541

TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33904
DATE : NOVEMBER 27, 1990
REPORT BY : ARNO HOOGVELD

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P.O.# P91 359 023

SAMPLING DATE : 90-11-20/21

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	37.48	24.90	13.20	24.43	3258
	A.D.	10.93	35.47	18.80	34.80	4642
	D.B.	----	39.82	21.11	39.07	5212
22:00 - 24:00	A.R.	37.52	25.55	12.93	24.00	3299
	A.D.	10.15	36.74	18.60	34.51	4744
	D.B.	----	40.89	20.70	38.41	5280
0:00 - 2:00	A.R.	37.83	25.88	11.86	24.43	3318
	A.D.	10.79	37.13	17.02	35.06	4761
	D.B.	----	41.62	19.08	39.30	5337
2:00 - 4:00	A.R.	37.64	26.22	11.49	24.65	3382
	A.D.	10.51	37.63	16.49	35.37	4853
	D.B.	----	42.05	18.43	39.52	5423
4:00 - 6:00	A.R.	37.22	25.36	13.80	23.62	3252
	A.D.	10.95	35.97	19.57	33.51	4613
	D.B.	----	40.39	21.98	37.63	5180
6:00 - 8:00	A.R.	37.01	25.17	13.85	23.97	3245
	A.D.	9.47	36.18	19.90	34.45	4664
	D.B.	----	39.96	21.98	38.05	5152

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ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33904
DATE : NOVEMBER 27, 1990
REPORT BY : ARNO HOOGVELD

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P.O.# P91 359 023

SAMPLING DATE : 90-11-20/21

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	10.93	50.01	3.58	0.66	18.80	0.91	15.11
22:00 - 24:00	10.15	50.37	3.78	0.64	18.60	0.87	15.59
0:00 - 2:00	10.79	51.11	4.07	0.66	17.02	0.70	15.65
2:00 - 4:00	10.51	51.70	3.68	0.61	16.49	0.75	16.26
4:00 - 6:00	10.95	48.75	3.78	0.64	19.57	0.87	15.44
6:00 - 8:00	9.47	49.54	3.68	0.60	19.90	1.07	15.74

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

629 BEAVERDAM ROAD N.E., CALGARY, ALBERTA.
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TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

PRPS
DEC 5 1990

FILE # : 33907
DATE : NOVEMBER 29, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 1

P.O.# P91 359 023

SAMPLING DATE : 90-11-21

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
8:00 - 10:00	A.R.	37.99	25.38	12.60	24.02	3198
	A.D.	8.96	37.27	18.50	35.27	4695
	D.B.	----	40.94	20.32	38.74	5157
10:00 - 12:00	A.R.	38.37	24.77	12.35	24.50	3207
	A.D.	8.85	36.64	18.27	36.24	4743
	D.B.	----	40.20	20.04	39.76	5204
12:00 - 14:00	A.R.	38.40	25.12	11.53	24.94	3241
	A.D.	10.28	36.59	16.80	36.33	4720
	D.B.	----	40.78	18.72	40.49	5261
14:00 - 16:00	A.R.	37.96	25.09	12.81	24.14	3203
	A.D.	8.44	37.03	18.91	35.62	4727
	D.B.	----	40.44	20.65	38.90	5163
16:00 - 18:00	A.R.	38.25	24.73	11.60	25.42	3256
	A.D.	8.07	36.82	17.27	37.84	4847
	D.B.	----	40.05	18.79	41.16	5272
18:00 - 20:00	A.R.	37.95	24.67	12.69	24.70	3214
	A.D.	7.37	36.82	18.94	36.87	4797
	D.B.	----	39.75	20.45	39.80	5179

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COAL ANALYSIS : LIFAC TEST

FILE # : 33907
DATE : NOVEMBER 29, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-21

--- ULTIMATE ANALYSIS, AIR DRIED ---

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
8:00 - 10:00	8.96	50.89	3.77	0.63	18.50	0.80	16.45
10:00 - 12:00	8.85	51.25	4.03	0.63	18.27	0.92	16.05
12:00 - 14:00	10.28	52.00	4.11	0.65	16.80	0.81	15.35
14:00 - 16:00	8.44	51.03	3.74	0.60	18.91	1.18	16.10
16:00 - 18:00	8.07	53.11	3.86	0.63	17.27	0.80	16.26
18:00 - 20:00	7.37	51.75	3.95	0.57	18.94	1.13	16.29

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

LORING LABORATORIES LTD.

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TO : SASKPOWER
ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33907
DATE : NOVEMBER 30, 1990
REPORT BY : ARNO HOOGVELD

P.O.# P91 359 023

SAMPLING DATE : 90-11-21/22

TIME:	BASIS	% H2O	% V.M.	% ASH	% F.C.	CAL/GM
20:00 - 22:00	A.R.	37.78	24.76	12.93	24.53	3223
	A.D.	9.51	36.01	18.81	35.67	4687
	D.B.	----	39.79	20.79	39.42	5180
0:00 - 2:00	A.R.	38.06	24.62	13.25	24.07	3171
	A.D.	5.39	37.61	20.24	36.76	4843
	D.B.	----	39.75	21.39	38.85	5119
2:00 - 4:00	A.R.	37.56	25.22	12.89	24.34	3212
	A.D.	7.97	37.17	18.99	35.87	4734
	D.B.	----	40.39	20.63	38.98	5144
4:00 - 6:00	A.R.	38.24	25.38	11.78	24.60	3251
	A.D.	7.75	37.91	17.59	36.75	4856
	D.B.	----	41.09	19.07	39.84	5264
6:00 - 8:00	A.R.	38.35	25.99	10.80	24.86	3309
	A.D.	9.44	38.18	15.87	36.51	4860
	D.B.	----	42.16	17.52	40.32	5367

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TEL : (403) 274-2777 FAX : (403) 275-0541

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ATTN : S. VAN DER HEIJDEN, TS&R
COAL ANALYSIS : LIFAC TEST

FILE # : 33907
DATE : NOVEMBER 30, 1990
REPORT BY : ARNO HOOGVELD

PAGE : 4

P.O.# P91 359 023

SAMPLING DATE : 90-11-21/22

— ULTIMATE ANALYSIS, AIR DRIED —

TIME :	%H2O	%C	%H	%N	%ASH	%S	%O
20:00 - 22:00	9.51	49.92	3.68	0.59	18.81	1.01	16.48
0:00 - 2:00	5.39	51.93	3.81	0.59	20.24	1.12	16.92
2:00 - 4:00	7.97	51.01	3.85	0.65	18.99	0.95	16.58
4:00 - 6:00	7.75	52.46	3.83	0.59	17.59	0.95	16.83
6:00 - 8:00	9.44	52.82	3.61	0.65	15.87	0.87	16.74

NOTE : Hydrogen and oxygen do not include H and O from sample moisture.
Value of oxygen by difference.

APPENDIX D

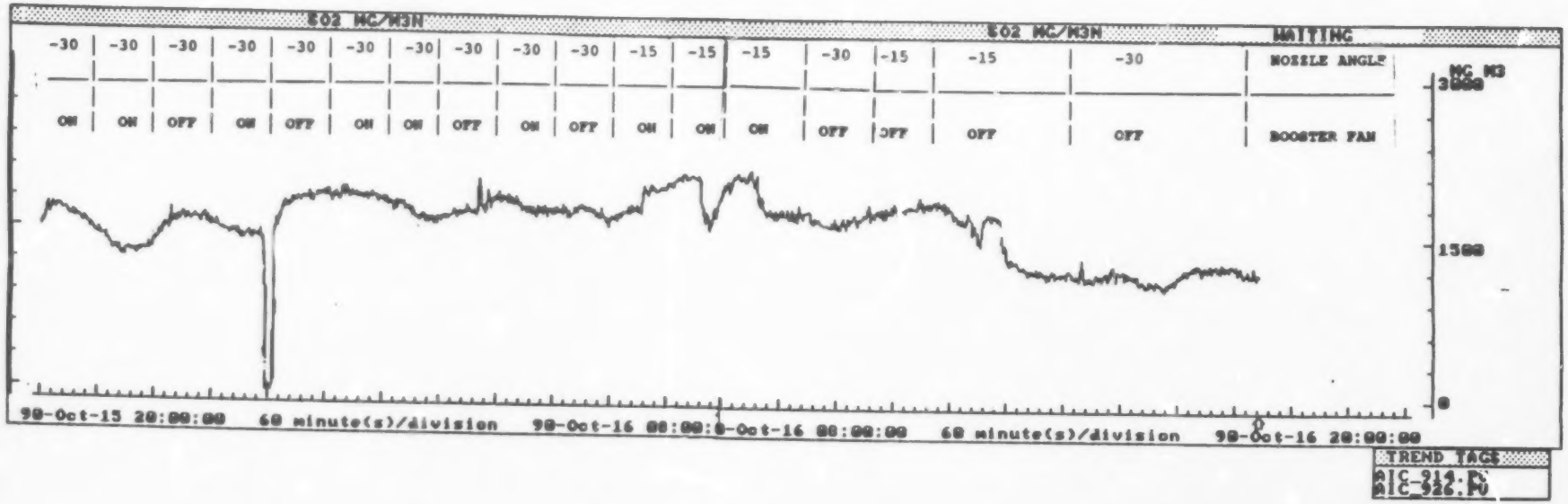
	date	time	load	lime	Measured baseline	Ca/S design	Ca/S coal	Tout	dT	recycle	Xinj	Xre	SO2 AT_914	Tfurnace	booster	inlet O2
			MW	Mg/h	mg/m3n	coal	analysis	C	C	A/B/C/D	%	%	mg/m3n	C	on/off	%
1	5.11.90	12:30	300	10	2186	2.2					7.7					
2	6.11.90	20:00	300	11	2357	2.4					13					
3	6.11.90	21:00	300	11		2.4		78	20	off		15				
4	6.11.90	23:00	300	14		3.0		70	12	off		38				
5	6.11.90	23:30	300	11		2.4		70	12	off		33				
6	7.11.90	00:30	300	11		2.4		68	10	off		44				
7	7.11.90	23:30	300	8.8	2143	1.9		66	8	AB	12	52				
8	8.11.90	04:15	300	8.8	2486	1.9					9.5					
9	8.11.90	06:00	300	8.8		1.9		66	8	AB		50				
10	13.11.90	12:40	300	11	2314	2.4	2.4	off		off	12	off			off	3.8
11	13.11.90	16:00	300	11		2.4	2.0	68	10	off		20			off	3.8
12	13.11.90	16:40	300	11	2400	2.4	2.0	65	7	off		26			off	3.8
13	13.11.90	18:40	300	11		2.4	2.1	64	6	off		29	1830	1349	off	3.6
14	13.11.90	19:30	300	11		2.4	2.1	63	5	off		35			off	3.6
15	13.11.90	20:20	300	11		2.4	2.3	62	4	off		37			off	3.8
16	13.11.90	22:40	300	11		2.4	2.0	61	3	off		40	2170	1325	off	3.8
17	14.11.90	03:30	300	11	2400	2.4	2.2	61	3	off		43	2043	1345	off	3.7
18	14.11.90	04:00	300	11	2400	2.4	2.2	off		off	16	off			off	3.7
19	14.11.90	08:00	300	11		2.4	2.0	65	7	off		30	2043	1340	off	3.5
20	14.11.90	11:00	300	11		2.4	2.0	63	5	off		39	2000	1350	off	3.2
21	14.11.90	12:00	300	11		2.4	2.0	63	5	off		36			off	3.2
22	14.11.90	13:00	300	11		2.4	2.0	63	5	off		42	1851	1320	off	3.2
23	14.11.90	14:40	300	11		2.4	2.4	63	5	AB		44			off	3.2
24	14.11.90	15:50	300	11									1915	1325	off	3.2
25	14.11.90	16:00	300	0									2213	1325	off	3.2
26	15.11.90	00:30	240	8	2529	2.2	2.1			off	19				off	3.3
27	15.11.90	01:20	240	8		2.2	2.1	68	10	off		26	2000	1240	off	3.3
28	15.11.90	02:40	200	4.7		1.5	1.3	68	10	off		27	1894	1220	off	4.4
29	15.11.90	03:00	180	4.7	2186	1.7	1.4				14				off	4.4
30	15.11.90	03:15	180	7.4	2186	2.7	2.2				27				off	4.4
31	15.11.90	03:40	180	7.4	2143	2.7	2.2				25		1574	1160	off	4.3
32	15.11.90	04:00	180	6.4	2143	2.3	1.9				23				off	4.3
33	15.11.90	05:10	180	6.4		2.3	2.2					43	1532	1215	off	4.6
34	15.11.90	06:20	220	6.4		1.9	1.8						1745	1160	off	4.6
35	15.11.90	07:00	220	6.4		1.9	1.8					40	1787	1220	off	5.5
36	15.11.90	07:15	220	8		2.3	2.1	62	4			46			off	4.2
37	15.11.90	08:10	300	10.5		2.3	1.9	62	4			47			off	3.3
38	15.11.90	10:30	300	10.5		2.3	2.1	62	4	AB		51	2106	1296	off	3.5
39	15.11.90	12:30	300	10.5		2.3	2.1	63	5	ABCD		49			off	3.5
40	15.11.90	13:20	300	10.5		2.3	2.1	63	5	ABCD		55			off	3.5
41	15.11.90	14:10	300	10.5		2.3	2.1	63	5	off		46	1915	1295	off	3.3
42	15.11.90	15:20	300	10.5		2.3	2.1	66	8	off		44			off	3.3

	date	time	load	lime	Measured baseline	Ca/S design	Ca/S coal	Tout	dT	recycle A/B/C/D	Xinj	Xre	SO2 AT_914	Tfurnace	booster inlet O2	
			MW	Mg/h	mg/m3n	coal	analysis	C	C		%	%	mg/m3n	C	on/off	%
43	15.11.90	21:50	300	10.5	2764	2.3	2.5	aff		aff	14	aff			aff	3.4
44	15.11.30	22:40	300	10.5		2.3	2.3		68	10 aff		22	1809	1170	aff	3.4
45	15.11.90	23:50	200	10.5		3.4	2.3		68	10 aff		28			50% flow	4.1
46	16.11.90	00:10	200	4.6		1.5	1.4		68	10 aff		20			50% flow	4.1
47	16.11.90	01:00	200	6.5	2871	2.1	1.8		68	10 aff	18	24	2000	1232	50% flow	4.1
48	16.11.90	01:15	200	6.5		2.1	1.8		63	5 aff		30			50% flow	4.1
49	16.11.90	01:30	200	8		2.6	2.4		63	5 aff		40			on	4.1
50	16.11.90	01:50	200	8		2.6	2.4		61	3 aff		40	1617	1205	on	4.1
51	16.11.90	03:00	200	8	2271	2.6	3.1		61	3 ABCD		68			on	4.2
52	16.11.90	03:15	200	8		2.6	3.1				27				on	4.2
53	16.11.90	03:30	200	6		1.9	2.6		61	3 ABCD		66			on	4.2
54	16.11.90	03:55	200	6		1.9	2.6		61	3 aff		43	1702	1185	on	4.2
55	16.11.90	04:30	200	6		1.9	2.0		61	3 AB or CD		46			on	4.3
56	16.11.90	05:40	200	6		1.9	2.0		60	2 ABCD		65	1915	1210	on	4.2
57	16.11.90	05:50	200	6		1.9	2.0		60	2 AB		51			on	4.2
58	16.11.90	07:00	300	5.8	2357	1.2	2.1			aff	17				on	3.8
59	20.11.90	10:20	300	3	2400	0.6		aff		aff	8					3.4
60	20.11.90	10:50	300	4.5		1.0		aff			19	*			?	3
61	20.11.90	13:50	300	4.5		1.0			65	? aff		17			?	4.5
62	20.11.90	14:20	300	4.5	2186	1.0		aff		aff	9				?	4.3
63	20.11.90	14:50	300	4.5	2057	1.0		aff		aff	11				?	4.3
64	20.11.90	16:10	300	11	1971	2.4		aff		aff	16				?	3.3
65	20.11.90	16:30	300	11	2143	2.4		aff		aff	16				?	3.3
66	20.11.90	19:30	300	11	1929	2.4		aff		aff	11				?	2.85
67	21.11.90	01:00	300	9.5	1886	2.0		aff		aff	16				aff	3.6
68	21.11.90	02:00	300	9.5		2.0			65	? aff		36	1617	1330	aff	3
69	21.11.90	04:12	300	9.5									2064	1335	aff	3.5
70	21.11.90	05:02	300										1957	1265	aff	3.5
71	21.11.90	06:10	300	9.5		2.0			65	? aff		40	2128	1160	on	3
72	21.11.90	06:40	300	9.5		2.0			65	? aff		34	2128	1140	on	1.8
73	21.11.90	06:55	300	9.5		2.0			65	? aff		31	2085	1175	on	1.8
74	21.11.90	07:15	300	9.5		2.0			65	? aff		35	1957	1330	aff	1.8
75	21.11.90	07:30	300	9.5		2.0			65	? aff		28			aff	3.2
76	21.11.90	08:50	300	9.5		2.0			65	? aff		26			aff	2.85
77	21.11.90	09:15	300	4		0.9			65	? aff		21			aff	2.85
78	21.11.90	09:50	300	4		0.9			65	? aff		26			on	2.85
79	21.11.90	10:20	300	8.5		1.8			65	? aff		35			on	2.85
80	21.11.90	10:50	300	8.5		1.8			65	? aff		37			on	2.85
81	21.11.90	11:50	300	12		2.6			65	? aff		52			on	2.85
82	21.11.90	13:40	300	12		2.6			65	? aff		47			on	2.96
83	21.11.90	17:40	300			2.4							1426	1248	aff	5.3
84	21.11.90	20:00	300	12		2.6			65	? ABCD		62			on	2.85
85	21.11.90	20:20	300	9.5		2.0			65	? ABCD		55			on	2.85
86	21.11.90	20:40	300	6		1.3			65	? ABCD		44			on	2.85
87	21.11.90	20:50	300	8.5		1.8			65	? ABCD		48			on	2.85
88	21.11.90	21:00	300	8.5		1.8			65	? aff		40			on	2.85
89	21.11.90	22:00	300	8.5	2614	1.8			65	? aff	10				on	2.85

	date	time	load	lime	Measured baseline	Ca/S design coal	Ca/S coal analysis	Tout	dT	recycle A/B/C/D	Xinj	Xre	SO2 AT_914	Tfurnace	booster	inlet O2
			MW	Mg/h	mg/m3n	coal		C	C		%	%	mg/m3n	C	on/off	%
90	27.11.90	13:20	300	11	2529	2.4		off		off	18				off	
91	27.11.90	14:00	300	11		2.4		62		4 off		50			on	2.9
92	27.11.90	14:40	200	11		3.6		62		4 off	37	59			on	4.8
93	27.11.90	15:40	200	11		3.6		62		4 ABCD	37				on	4.8
94	27.11.90	21:30	300	11		2.4		64		6 ABCD		42			on	2.85
95	28.11.90	02:10	300	10.7	2571	2.3					13					
96	28.11.90	11:00	300	10.6	2443	2.3					16					
97	28.11.90	04:00	300	10.6	2357	2.3		64		6 off		47			on	3.2
98	28.11.90	05:30	300	10.6		2.3		64		6 ABCD		52			on	2.85
99	28.11.90	09:30	300	10.6		2.3		64		6 ABCD		52			on	2.8
100	28.11.90	16:00	300	10.6		2.3		64		6 ABCD		43			on	3.3
101	28.11.90	22:30	300	11		2.4		64		6 off		45			on	2.85
102	28.11.90	23:30	300	11		2.4		64		6 ABCD		60			on	2.85
103	29.11.90	03:00	300	12.7	2786	2.7					8					
104	29.11.90	05:30	300	12.7		2.7		64		6 ABCD		59			on	2.85
105	29.11.90	09:00	300	12.7		2.7		64		6 ABCD		61			on	2.85
106	29.11.90	14:15	300	11.3	2657	2.4					13					
107	29.11.90	21:00	300	11	1993	2.4					14					
108	29.11.90	23:30	300	11		2.4		64		6 ABCD		62				
109	30.11.90	05:30	300	11		2.4		64		6 ABCD		51			on	2.8
110	30.11.90	18:00	300	9.5	2529	2.0					11					
111	1.12.90	01:30	300	11		2.4		64		6 ABCD		48			on	2.7
112	1.12.90	03:15	300	11	2914	2.4					17				on	3.2
113	1.12.90	07:30	300	11		2.4		64		6 ABCD		50			on	2.85
114	1.12.90	10:10	300	11.4	2571	2.5					9.4				on	2.85
115	1.12.90	15:00	300	11.4		2.5		64		6 ABCD		52	2126	1310	off	2.9
116	1.12.90	16:10	300	11.4		2.5		64		6 ABCD		42	1787	1145	off	5.5
117	1.12.90	22:00	300	11.4	2571	2.5					13				off	3.2
118	1.12.90	23:00	300	11.4		2.5		64		6 off		29			off	3.2
119	1.12.90	23:30	300	11.4		2.5		64		6 ABCD		50			off	3.2
120	2.12.90	02:00	300	11.4		2.5		64		6 ABCD		51	1915	1350	off	3.7
121	2.12.90	02:40	300	11.4		2.5		64		6 ABCD		55			off	4.7
122	2.12.90	03:30	300	11.4		2.5		64		6 ABCD		46			off	4.7
123	2.12.90	04:40	300	11.4		2.5		64		6 ABCD		49	1745	1250	off	3.2
124	2.12.90	05:40	300	11.4		2.5		64		6 ABCD		54			on	3.2
125	2.12.90	08:00	300	11.4		2.5		64		6 ABCD		53			on	3.3
126	2.12.90	11:10	300	11.4		2.5		64		6 ABCD		46			off	2.9
127	2.12.90	13:00	300	11.4		2.5		64		6 ABCD		53			on	3
128	2.12.90	13:45	300	11.4									1745	1345	off	2.9
129	2.12.90	14:00	300	11.4		2.5		64		6 ABCD		41			off	5.6
130	2.12.90	14:20	300										1745	1225	off	5
131	2.12.90	15:00	300	11.4		2.5		64		6 ABCD		48			off	3.3
132	2.12.90	16:00	300	11.4		2.5		64		6 ABCD		44			off	3.3
133	2.12.90	17:00	300	11.4		2.5		64		6 ABCD		43			on	2.85
134	2.12.90	18:00	300	11.4		2.5		64		6 ABCD		46			on	3
135	2.12.90	19:00	300	10.7	2100	2.3		64		6 ABCD	12	51			on	3
136	2.12.90	22:00	300	10.7		2.3		64		6 AB		40			on	2.85
137	2.12.90	22:30	300	10.7		2.3		64		6 ABCD		53			on	2.85

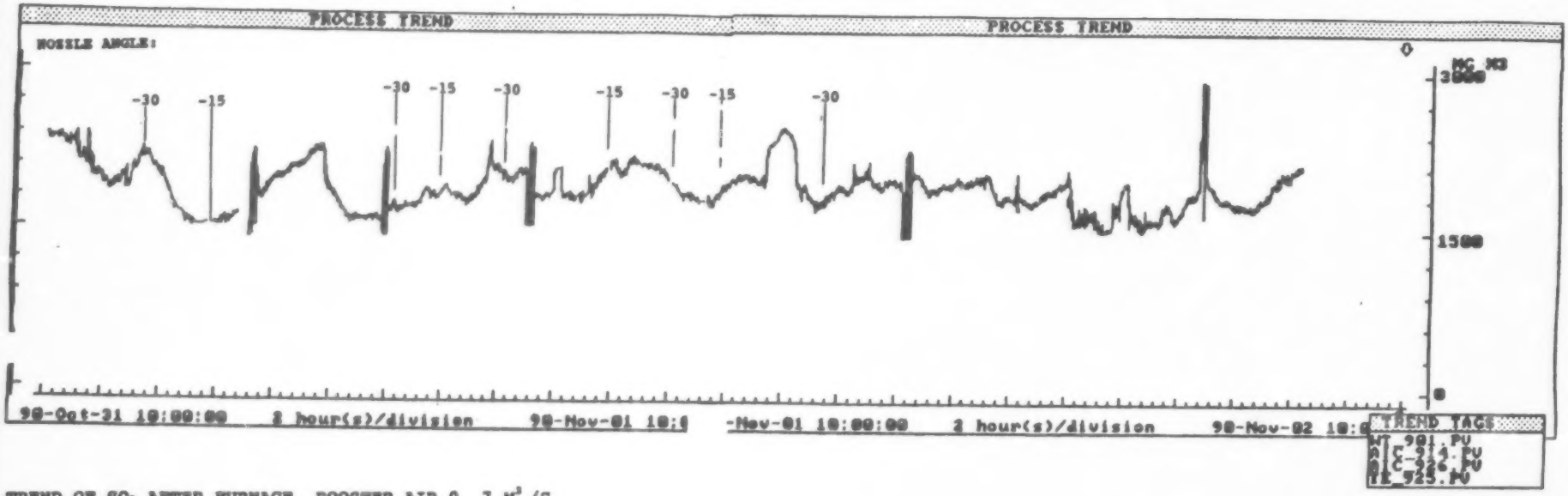
	date	time	load	lime	Measured baseline	Ca/S design	Ca/S coal	Tout	dT	recycle	Xinj	Xre	SO2 AT_914	Tfurnace	booster	inlet O2
			MW	Mg/h	mg/m3n	coal	analysis	C	C	A/B/C/D	%	%	mg/m3n	C	on/off	%
138	2.12.90	22:50	300	10.7		2.3			64	6 off		39			on	2.85
139	3.12.90	01:30	300	9		1.9			64	6 ABCD		53			on	2.8
140	3.12.90	02:30	300	9		1.9			64	6 CD		43			on	2.9
141	3.12.90	03:15	300	9		1.9			64	6 CD		42			on	2.9
142	3.12.90	03:50	300	9		1.9			64	6 ABCD		49			on	2.9
143	3.12.90	04:20	300	9		1.9			64	6 off		29			on	2.8
144	3.12.90	04:50	300	9		1.9			64	6 ABCD		42			on	2.8
145	3.12.90	06:00	300	9	2186	1.9			64	6 off	9	34			on	2.8
146	3.12.90	06:30	300	9		1.9			64	6 ABCD		49			on	2.8
147	3.12.90	07:15	300	9		1.9			64	6 off		36			on	2.8
148	3.12.90	07:50	300	9		1.9			64	6 ABCD		54			on	2.8
149	3.12.90	10:00	300	9	2486	1.9		off		off	10				on	4
150	3.12.90	11:00	300	9	2614	1.9		off		off	16				on	3.8
151	3.12.90	12:00	300	10		2.2			64	6 off		36			on	3.5
152	3.12.90	14:00	300	10		2.2			64	6 ABCD		52			on	2.9
153	3.12.90	16:00	300	11		2.4			64	6 ABCD		45			on	2.9
154	3.12.90	18:00	300	11.4	2155	2.5			64	6 ABCD	15	46			on	2.9
155	3.12.90	18:30	300	11.4		2.5			64	6 off		35			on	2.9
156	3.12.90	19:00	300	11.4		2.5			64	6 ABCD		50			on	2.9
157	3.12.90	21:00	300	11.4		2.5			64	6 off		42			on	2.9
158	3.12.90	21:40	300	11.4		2.5			64	6 off		41			off	2.9
159	3.12.90	22:00	300	11.4		2.5			64	6 ABCD		54			off	2.9
160	3.12.90	23:15	300	11.4		2.5			64	6 ABCD		57			on	3.3
161	4.12.90	00:00	300	11.4		2.5			64	6 ABCD		51			off	2.9
162	4.12.90	01:30	300	11.4		2.5			64	6 ABCD		61			on	2.9
163	4.12.90	02:30	300	11.4		2.5			64	6 ABCD		52			off	3
164	4.12.90	03:30	300	11.4		2.5			64	6 ABCD		62			on	3
165	4.12.90	04:30	300	11.7	1929	2.5					21					
166	4.12.90	05:30	300	11.7		2.5			64	6 ABCD		57			off	3
167	4.12.90	06:30	300	11.7		2.5			64	6 ABCD		58			on	3
168	4.12.90	09:30	300	11.7		2.5			64	6 ABCD		52			on	3
169	4.12.90	10:15	300	11.7		2.5			64	6 off		45			on	3
170	4.12.90	21:15	300	9.5	2119	2.0		off			17				on	3.3
171	4.12.90	22:30	300	9.5		2.0			70	12 ABCD		25			on	3.3
172	4.12.90	23:30	300	9.5		2.0			70	12 AB		18			on	3.3
173	5.12.90	00:30	300	9.5		2.0			70	12 CD		18			on	3.3
174	5.12.90	01:10	300	9.5		2.0			70	12 ABCD		22			on	3.3
175	5.12.90	02:30	200	4.5		1.5			62	4 off		18	1574	1150	off	5.4
176	5.12.90	03:00	200	4.5		1.5			62	4 off		34			off	low
177	5.12.90	03:20	200	4.5	1886	1.5					19		1886	1210	off	3.2
178	5.12.90	03:40	200	7.8		2.5			62	4 off	24	38			off	low
179	5.12.90	04:00	200	3.5		1.1			62	4 off	12	29			off	low
180	5.12.90	04:15	200	4.5		1.5			62	4 off		34			off	low
181	5.12.90	04:20	200	4.5	2100	1.5					21				off	low
182	5.12.90	16:10	300	9.8	1800	2.1					17				on	3
183	5.12.90	18:00	300	9.8		2.1			62	4 ABCD		61			on	3
184	5.12.90	24:00	300	9.8		2.1			62	4 ABCD		58			on	3
185	6.12.90	02:30	300	9.8		2.1			62	4 ABCD		60			on	2.9

	date	time	load	lime	Measured baseline	Ca/S design	Ca/S coal	Tout	dT	recycle A/B/C/D	Xinj	Xre	SO2 AT_914	Tfurnace	booster	inlet O2
			MW	Mg/h	mg/m3n	coal	analysis	C	C		%	%	mg/m3n	C	on/off	%
186	6.12.90	09:30	300?	9.1	1976	BRR					16				on	3.8
187	6.12.90	10:30	300?	9.1		BRR		62		4 ABCD		56			on	2.9
188	6.12.90	14:00	300	10		2.2		62		4 ABCD		50			on	3.2
189	6.12.90	15:30	300	10		2.2		62		4 ABCD		60			on	3.2
190	6.12.90	17:00	300	10		2.2		62		4 ABCD		63			on	3.2
191	6.12.90	18:15	300	10		2.2		62		4 ABCD		54			on	3.2
192	6.12.90	21:00	300	10		2.2		62		4 ABCD		57			on	3.2
193	6.12.90	22:00	300	10		2.2		62		4 ABCD		56			on	3.2
194	6.12.90	23:00	300	10		2.2		62		4 ABCD		51			on	3.2
195	7.12.90	04:45	300	10		2.2					13					
196	7.12.90	09:15	300	10	2079	2.2		70	12	off	15	27				
197	7.12.90	12:15	300	9.5	2400	2.0					14				on	3.2
198	7.12.90	13:30	300	9.5		2.0		62	4	off		46			on	3.2
199	7.12.90	17:00	300	9.5		2.0		62	4	ABCD		57			on	3.2
200	7.12.90	19:00	300	9.5		2.0		62	4	ABCD		60			on	3.2
201	7.12.90	21:00	300	9.4	2571	2.0		62	4	ABCD	12	56			on	3.2
202	7.12.90	22:30	300	9.5		2.0		62	4	ABCD		63			on	3.2
203	7.12.90	24:00	300	9.5		2.0		62	4	ABCD		60			on	3.2
204	8.12.90	03:50	200	5		1.6		62	4	off		57			on	3
205	8.12.90	04:45	200	5		1.6		62	4	off		52	1702	1105	on	4.9
206	8.12.90	05:05	200	5		1.6		62	4	off		48			on	2.6
207	8.12.90	05:20	200	5		1.6		62	4	off		61			on	3
208	8.12.90	05:30	200	5		1.6		62	4	off		53	1957	1163	on	3.3
209	8.12.90	06:00	200	5	2286	1.6		62	4	off	15	46			on	2.6
210	8.12.90	06:20	200	8.5		2.7		62	4	off		60			on	2.6
211	8.12.90	06:30	200	8.5		2.7		62	4	ABCD		84			on	2.6
212	8.12.90	06:40	200	8.5		2.7		62	4	ABCD		81			on	4.8
213	8.12.90	10:00	300	12.2		2.6					20				on	3.5
214	8.12.90	11:10	300	12.2		2.6		62	4	ABCD		72			on	3.5



TREND OF SO_2 AFTER FURNACE

APPENDIX E
Page 1(2)



TREND OF SO_2 AFTER FURNACE, BOOSTER AIR 0, 7 M^3_n/S

APPENDIX F

Booster air changes

Date	Time	on/off 1/2	dSO2 %	Load MW	Note
02-Dec-90	10:15		0	300	
04-Dec-90	00:47	1	-5.7	300	
16-Oct-90	01:00	1	0	300	
16-Nov-90	01:20	1	0	200	
08-Nov-90	01:20	1	0	300	
16-Nov-90	02:00	1	0	200	
08-Nov-90	02:30	1	-5.4	300	
04-Dec-90	02:55	1	-4.2	300	
16-Oct-90	04:00	1	0	300	
16-Oct-90	04:00	1	0	300	
02-Dec-90	05:05	1	0	300	
21-Nov-90	05:30	1	0	300	
16-Nov-90	05:45	1	0	200	5% open
16-Oct-90	06:00	1	0	300	5% to max
16-Oct-90	06:00	1	-3	300	max to 5%
04-Dec-90	06:20	1	0	300	5% to max
21-Nov-90	09:30	1	0	300	
05-Dec-90	10:23	1	0	300	
02-Dec-90	11:30	1	0	300	
18-Oct-90	14:50	1	-7.7	300	
02-Dec-90	16:15	1	-4.4	300	
30-Oct-90	21:10	1	0	300	
03-Dec-90	22:45	1	-2.6	300	
15-Oct-90	23:00	1	0	300	.7 to .4
15-Nov-90	23:30	1	0	200	
16-Oct-90	00:00	2	0	300	
04-Dec-90	01:45	2	3.1	300	
08-Nov-90	01:47	2	0	300	
16-Nov-90	01:50	2	0	200	
16-Oct-90	03:00	2	0	300	
16-Oct-90	03:00	2	0	300	
16-Oct-90	05:00	2	0	300	
16-Oct-90	05:04	2	0	300	
16-Nov-90	05:40	2	0	200	
21-Nov-90	07:00	2	0	300	
16-Oct-90	09:20	2	0	300	
02-Dec-90	11:00	2	0	300	

Date	Time	on/off 1/2	dSO2 %	Load MW	Note
18-Oct-90	13:30	2	4.3	300	
02-Dec-90	13:40	2	-2.4	300	
01-Dec-90	14:56	2	0	300	
15-Oct-90	20:45	2	0	300	
30-Oct-90	21:20	2	0	300	
03-Dec-90	21:40	2	3.6	300	
15-Oct-90	22:00	2	0	300	

THE IMMEDIATE EFFECT OF CHANGES IN RECYCLE MODE

Change codes:

1 - OFF TO AB
2 - OFF TO ABCD
3 - OFF TO CD
4 - AB TO OFF
5 - ABCD TO OFF
6 - CD TO OFF
7 - AB TO CD
8 - CD TO AB
9 - ABCD TO AB
10 - ABCD TO CD
11 - CD TO ABCD
12 - AB TO ABCD

Date	Time	Change (1 to 12)	Load MW	dT C	Ca/S -	X1 %	X2 %	dX %
16-Nov-90	04:00	1	200	3	2	44	46	5
07-Nov-90	01:00	1	300	10	2.4	44	45	2
14-Nov-90	14:15	1	300	5	2.4	41	45	10
15-Nov-90	09:20	1	300	4	1.9	46	49	7
08-Nov-90	05:10	1	300	8	1.9	44	50	14
01-Dec-90	23:15	2	300	6	2.5	29	43	48
28-Nov-90	22:50	2	300	6	2.4	45	60	33
03-Dec-90	21:50	2	300	6	2.5	41	54	32
21-Nov-90	18:00	2	300	7	2.4	51	51	0
03-Dec-90	06:10	2	300	6	1.9	34	49	44
03-Dec-90	18:38	2	300	6	2.5	35	50	43
03-Dec-90	07:35	2	300	6	1.9	36	54	50
28-Nov-90	04:38	2	300	6	2.3	45	46	2
04-Dec-90	10:00	4	300	6	2.5	43	45	5
03-Dec-90	06:55	5	300	6	1.9	45	36	-20
03-Dec-90	04:10	5	300	6	1.9	41	29	-29
03-Dec-90	18:22	5	300	6	2.5	44	35	-20
15-Nov-90	13:40	5	300	5	2.1	55	48	-13
05-Dec-90	00:00	7	300	12	2	18	20	11
16-Nov-90	04:35	7	200	3	2	46	43	-7
04-Dec-90	09:40	9	300	6	2.5	52	43	-17
04-Dec-90	23:00	9	300	12	2	25	18	-28
02-Dec-90	21:20	9	300	6	2.3	42	40	-5
03-Dec-90	01:50	10	300	6	1.9	48	43	-10
03-Dec-90	03:30	11	300	6	1.9	42	49	17
16-Nov-90	05:00	11	200	3	2	43	60	40
05-Dec-90	00:51	11	300	12	2	20	21	5
02-Dec-90	22:20	12	300	6	2.3	40	53	33
16-Nov-90	06:30	12	300	2	2.1	58	66	14
15-Nov-90	12:05	12	300	5	2.1	50	50	0

Tampella
0203k

APPENDIX I

TRANSLATION

REPORT 4.7.1990

STUDY OF LIMESTONE INJECTION/COMPARISON OF CANADIAN LIMESTONE TYPES

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1. OBJECTIVES OF THE STUDY

The objective of this study was to compare the desulfurization properties of two Canadian limestone types, i.e. Inland Cement and Continental Lime. In addition to mutual comparison, the results were also compared with the results obtained earlier with the limestone from Gotland.

The degree of limestone utilization and activity obtained on the basis of temperature rise during slaking were used as comparison criteria. Specific area definitions and SEM-imaging carried out with an electron microscope are also presented as research results.

2. EXPERIMENTAL ARRANGEMENTS

The differences in the results caused by particle size were eliminated, as far as possible, by pulverizing the limestone into about the same particle size as the limestone from Gotland. The particle size distributions are presented in Appendix 1. The impurity of the Inland Cement limestone was about 9.1 percent by weight and that of the Continental Lime limestone 2.6 percent by weight, while the impurity of the limestone from Gotland is 6.6 percent by weight.

The experiments were performed with the drop tube in Tampella's Air Pollution Control workshop, in an atmosphere (14% CO_2, 4% O_2, 8% H_2O, 0.1%, SO_2, remaining N_2) almost corresponding to the normal boiler conditions. The flue gas flow velocity was about 8 m/s, at which turbulent flow conditions are achieved. The Ca/S molar ratio was $\approx$ 2. The test temperatures were 1040°C and 1090°C and one experiment was performed at a temperature of 990°C.

The S content in the solid specimens obtained from the experiment was analysed in Tampella's R&D laboratory. The calcination degree was determined in the Institute of Chemistry at Oulu University, where recarbonation was also observed.

The limestone activity was determined selectively on some specimens in Tampella's R&D laboratory. The specific surface areas of the same specimens were determined by the mercury porosimeter in the Institute of Microelectronics at Oulu University. The specimens were also examined by an electron microscope at Oulu University.

3. RESULTS OF THE LIMESTONE COMPARISONS

The calcination velocities of all limestone types are approximately the same (Tables 1 and 2 in Appendix 2 and Table 3 in Appendix 3). Calcination is extremely rapid and a 90% calcination degree is reached in abt. 0.1 sec. Slight differences, if any, can be attributed to experimental inaccuracies.

On the other hand, there was some difference in the sulfur removal capacity and activity of the different limestone types.

3.1 Comparison of limestone types in terms of sulfur removal capacity

The comparison of the limestone types at two different temperatures is presented in Appendixes 4 and 5. The basis of the comparison was the sulfur removal capacity of limestone, which is expressed in SO_2 reduction at the Ca/S molar ratio 2. The molar ratio was about 2 in all experiments, and since it was evident from the previous experiments that slight variation in the molar ratio near the target value had no big effect on the sulfatization reaction, the above-mentioned calculation and comparison could be performed justifiably.

The comparison includes the results of the available residence times (0.09, 0.24 and 0.32 sec); they are about what is possible to reach on the boiler scale.

3.1.1 Comparison of the limestone types at a temperature of 1040°C

The sulphur removal capacity of the different limestone types at a temperature of 1040°C is presented in Figure 2 of Appendix 4. The following conclusions can be drawn of the results:

1. At the Ca/S ratio 2, an SO_2 reduction of 20% is reached within less than 0.1 sec both with the limestone from Gotland and with the Inland Cement limestone, whereas the SO_2 reduction yielded by the Continental Lime limestone is only about 12%.

2. Using two longer residence times the results with the limestone from Gotland are a little better than those with the Inland Cement limestone, but experimental inaccuracies must be considered. The results with the Continental Lime limestone are clearly poorer than the two other and an SO_2 reduction of only about 20% is obtained with it.

3. The limestone types were ranked at a temperature of 1040°C as follows: limestone from Gotland, Inland Cement and Continental Lime.

3.1.2 Comparison of limestone types at a temperature of 1090°C

The results of the experiment are presented in Figure 3 of Appendix 5.

1. With the shortest residence time the best SO_2 reduction is reached with the limestone from Gotland and Inland Cement; the results are about 24-26%; the result of Continental Lime remains at abt. 20%.

2. With a residence time of 0.24 sec SO_2 reduction both with limestone from Gotland and with Inland Cement is abt. 30%, whereas Continental Lime reaches an SO_2 reduction of only abt. 25%.

3. With the longest residence time the sulfur removal capacity of Inland Cement is increasingly enhanced and is abt. 40%; the difference between it and the two other is quite clear.

3.2 Comparison of the limestone types in terms of activity and specific surface area

Temperature rise during slaking was examined on three different specimens of limestone; residence times of 0.09 sec and 0.24 sec at 1090°C and a residence time of 0.24 sec at 990°C. The different results of all limestone types were compared with each other and the results of the different limestone types with each other. When examining the temperature rise during slaking, an approximately equal quantity of desulfurization compound to be tested (in this case abt. 5 g, containing abt. 3 g CaO) was mixed with 60 ml water and the temperature rise caused by the reaction between CaO and water was measured.

Efforts were also made to measure the activity of the above-mentioned specimens by specific surface area measurements. The use of specific surface area for determining activities was justified by the fact that the calcination and sulfatization degrees were about the same, and consequently it was considered that the difference in the specific surface area was caused merely by sintering.

3.2.1 Definitions of activity and specific surface area at 990°C

The results of the examination of temperature rise during slaking in the experiments performed at 990°C are presented in Table 4 of Appendix 6. The results show that the activity of Inland Cement is clearly the best. The activities of the limestone from Gotland and Continental Lime limestone are approximately the same.

The same table also presents the specific surface area definitions of the different limestone types.

3.2.2 Activity and specific surface area definitions at 1090°C

The results of the examination of temperature rise during slaking at 1090°C are presented in Table 4 of Appendix 6. The results show that the activity of Inland Cement is somewhat better than that of the limestone from Gotland, which, in terms of activity, differs clearly from Continental Lime.

If the results of each limestone type with a residence time of 0.24 sec at 990°C and 1090°C are compared with each other, it can be seen that the result at 990°C is better. This is due to sintering, which is the more extensive the higher the temperature.

The above-mentioned result is also supported by the results obtained from the specific surface area definitions (Table 4 and Figure 4 in Appendix 6); from these it can be seen that the specific surface areas at 990°C are clearly bigger than those at 1090°C. If the results of two different residence times at 1090°C are compared with each other, it can be seen that a better result, in terms of activity, is obtained with a shorter delivery time. If, in addition, the degree of utilization is taken into account, a compromise must be made concerning the degree of utilization and activity when trying to find the optimum residence time; the longer the residence time, the better the degree of utilization yet worse reactivity in view of continuation, i.e. activation.

3.3 Electron microscope examinations

Images by the electron microscope were taken to examine the morphology of the specimens. Strong shock heating does not cause visible changes in the particles; small cracks were found only in the bigger particles. No visible sintering between particles can be seen from the pictures. In the conditions in question, sintering will occur on the surface of each particle, which cannot be seen from the pictures.

Because of a small particle size cross-profile analyses could not be performed reliably.

The images by the electron microscope are presented in Appendixes 7-12.

4. SUMMARY OF THE CANADIAN LIMESTONE TYPES

When comparing two Canadian limestone types, Inland Cement and Continental Lime, Inland Cement is found better. If the degree of utilization is used as a criterion, the results obtained with the better Canadian limestone are about the same as those obtained with the limestone from Gotland at the temperatures of 1040°C and 1090°C.

If, in addition, activity is taken into account, Inland Cement can be said to be somewhat more active than the limestone from Gotland. The above-mentioned result, however, can be affected a little by the slightly finer particle distribution of the limestone in question compared with the limestone from Gotland (Figure 1 of Appendix 1).

On the basis of the above, Inland Cement seems to be, in injection, very heat resistant, which is indicated by the high desulfurization degree and, among the limestone types examined, the best activity to after-reactions, if any.

When making a definite analysis of the economy and efficiency of the different limestone types, the impurities must also be taken into account and the price of limestone must be evaluated rather on the basis of the price of calcium than the price per tonne.

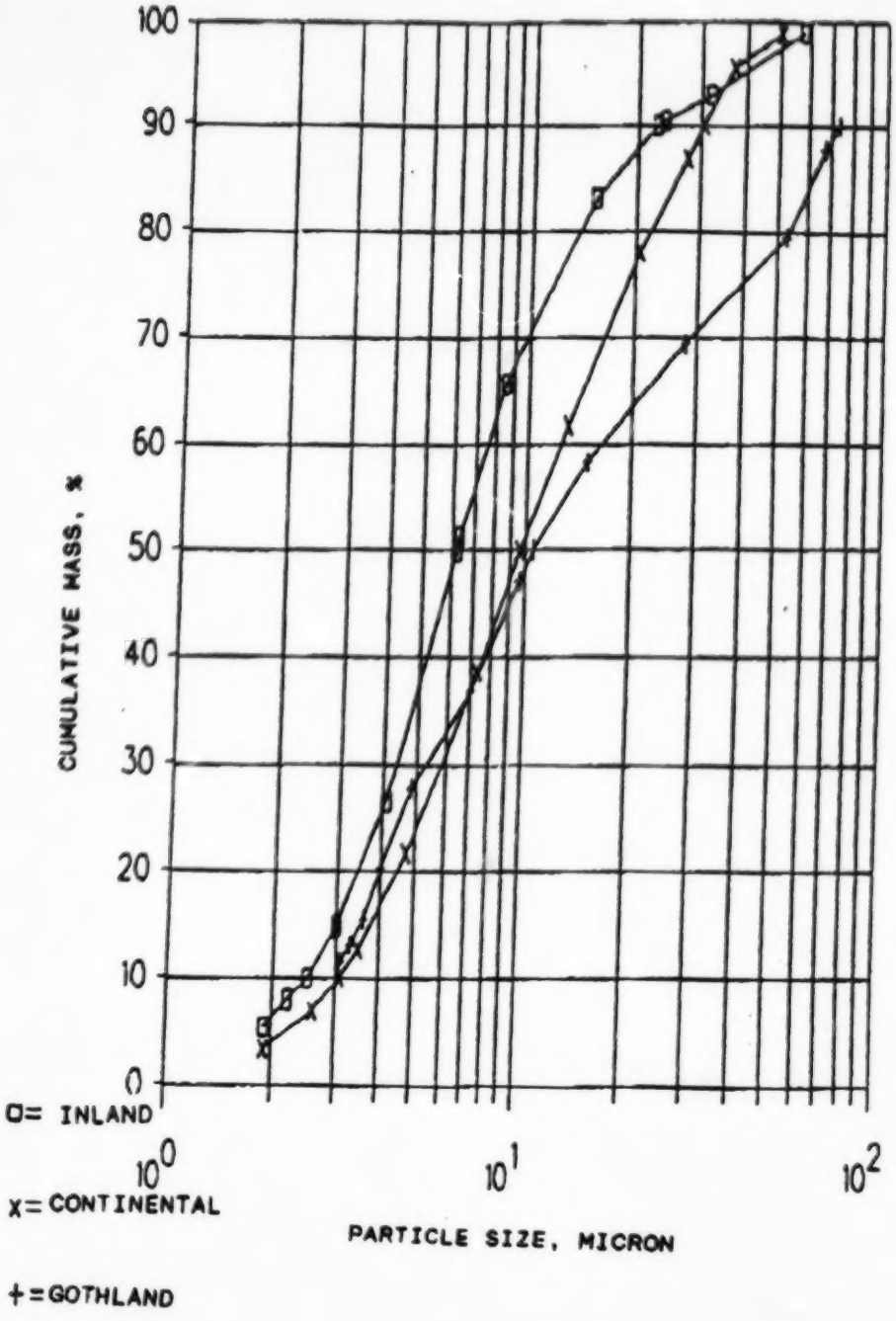


Fig. 1. Particle size distributions of Inland Cement, Continental Lime and Gothlandic limestones

Table 1. Results of sulfation tests (Inland Cement)

T °C	t s	Ca/S	X_{CaCO_3} solid	S-cont mass-%	U solid	X_{SO_2} solid	SO_2 ppm
990.0	.24	1.9	.93	4.76	.116	.221	1000.
1040.0	.09	2.1	.91	4.17	.102	.214	1000.
1040.0	.24	1.7	.96	5.55	.136	.232	1000.
1040.0	.32	1.9	.97	5.91	.146	.277	1000.
1090.0	.09	1.7	.96	5.45	.133	.227	1000.
1090.0	.24	2.3	.98	5.92	.145	.333	1000.
1090.0	.32	1.6	.98	7.58	.196	.313	1000.

Table 2. Results of sulfation tests (Continental Lime)

T °C	t s	Ca/S	X_{CaCO_3} solid	S-cont mass-%	U solid	X_{SO_2} solid	SO_2 ppm
990.0	.24	1.9	.96	4.82	.104	.197	1000.
1040.0	.09	3.1	.90	2.89	.061	.190	1000.
1040.0	.24	2.7	.92	3.63	.077	.209	1000.
1040.0	.32	2.3	.97	5.02	.108	.247	1000.
1090.0	.09	1.7	.95	4.60	.099	.168	1000.
1090.0	.24	2.3	.98	5.33	.114	.262	1000.
1090.0	.32	2.1	.97	5.72	.125	.262	1000.

Table 3. Results of sulfation tests (Limestone from Gothland)

T °C	t s	Ca/S	X_{CaCO_3} solid	S-cont mass-%	U solid	X_{SO_2} solid
1040.0	.09	2.1	.88	4.61	.111	.234
1040.0	.24	2.0	.96	6.71	.163	.326
1040.0	.32	2.1	.96	7.29	.180	.378
1090.0	.09	1.4	.88	4.89	.119	.167
1090.0	.24	1.6	.96	6.12	.146	.234
1090.0	.32	2.5	.96	6.26	.150	.374

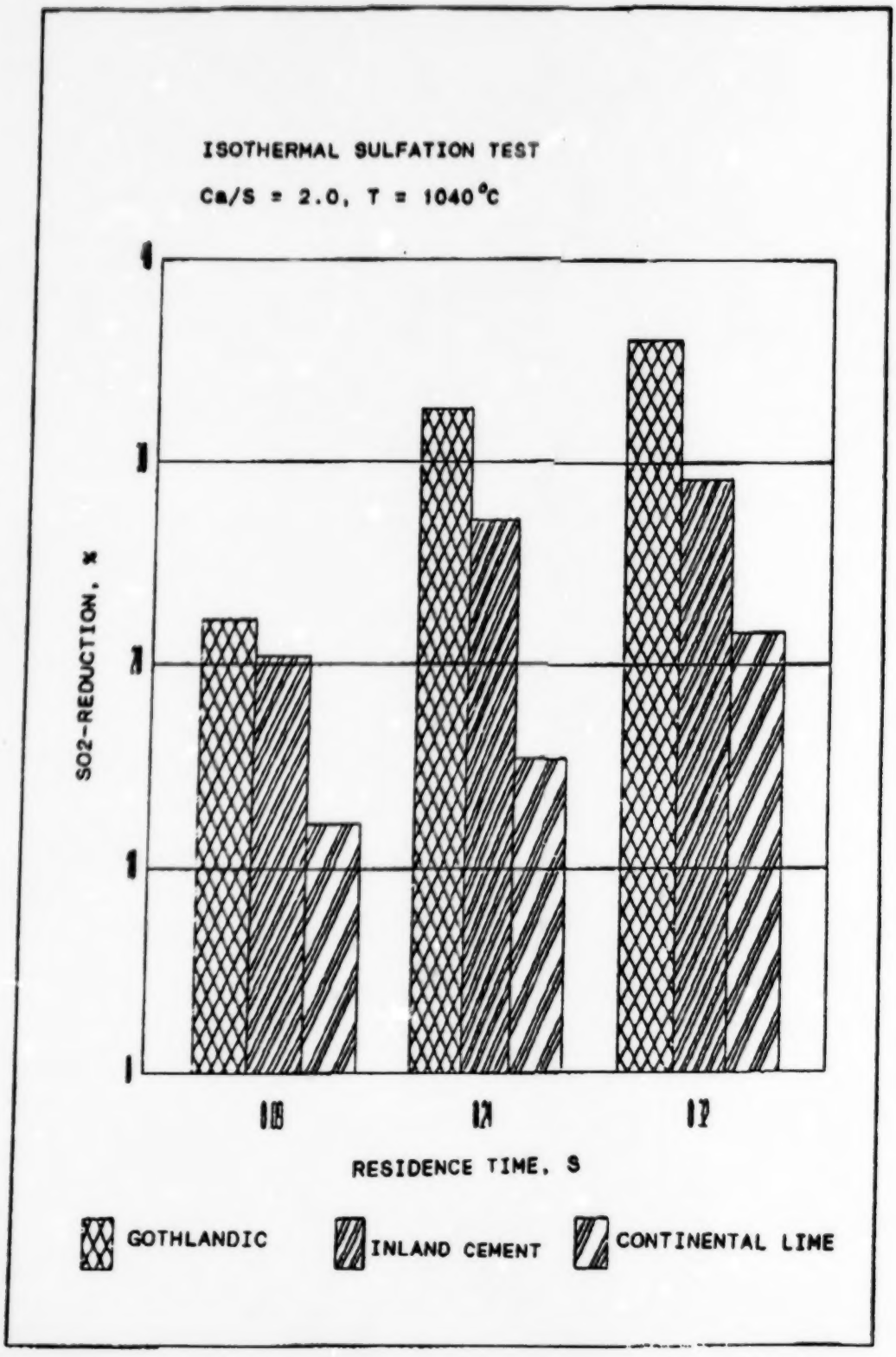


Fig. 2. Comparison of limestones when temperature is 1040°C

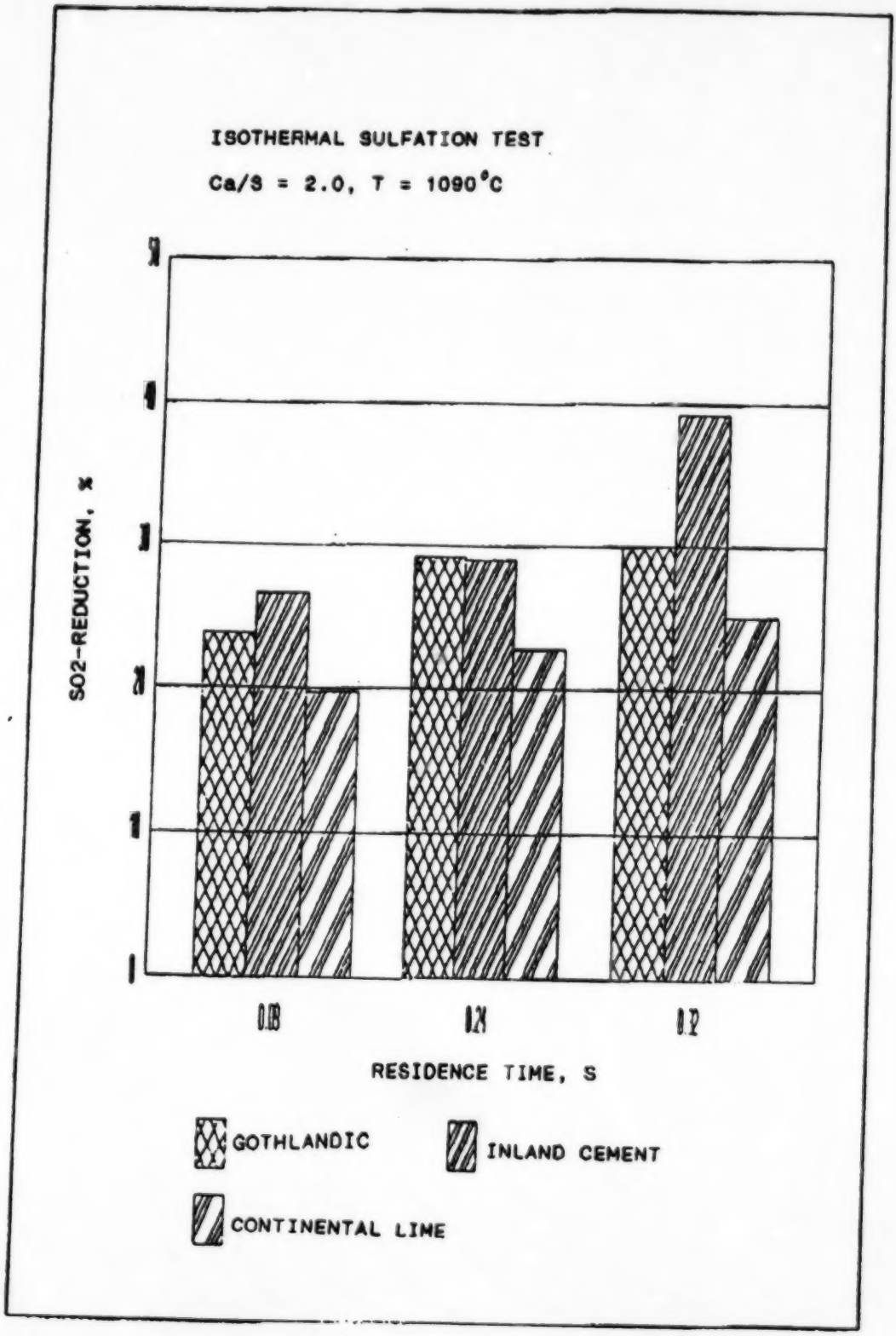


Fig. 3. Comparison of limestones when temperature is 1090°C

Table 4. Definition of slaking curve and spesific area under temperatures 990 °C and 1090 °C

Limestone	T	Mass of sample	Mass of CaO	Temp. rise in 3s	Temp. rise/ CaO	Spesific area
	s	g	g	°C	°C/gCaO	m^2/g
Temperature 990°C:						
Gothlandic	0.24	5.01	2.45	7.35	2.99	17.3
Inland	0.24	5.01	2.68	9.48	3.53	18.2
Continent.	0.24	5.01	3.29	10.20	3.10	17.7
Temperature 1090°C:						
Gothlandic	0.09	5.05	2.38	7.88	3.30	13.5
- " -	0.24	5.00	2.85	7.68	2.69	12.3
Inland	0.09	4.56	2.46	8.37	3.39	15.4
- " -	0.24	5.02	2.84	8.56	3.02	9.9
Continent.	0.09	5.01	3.22	8.30	1.96?	14.7
- " -	0.24	5.01	3.38	8.81	2.55	11.4

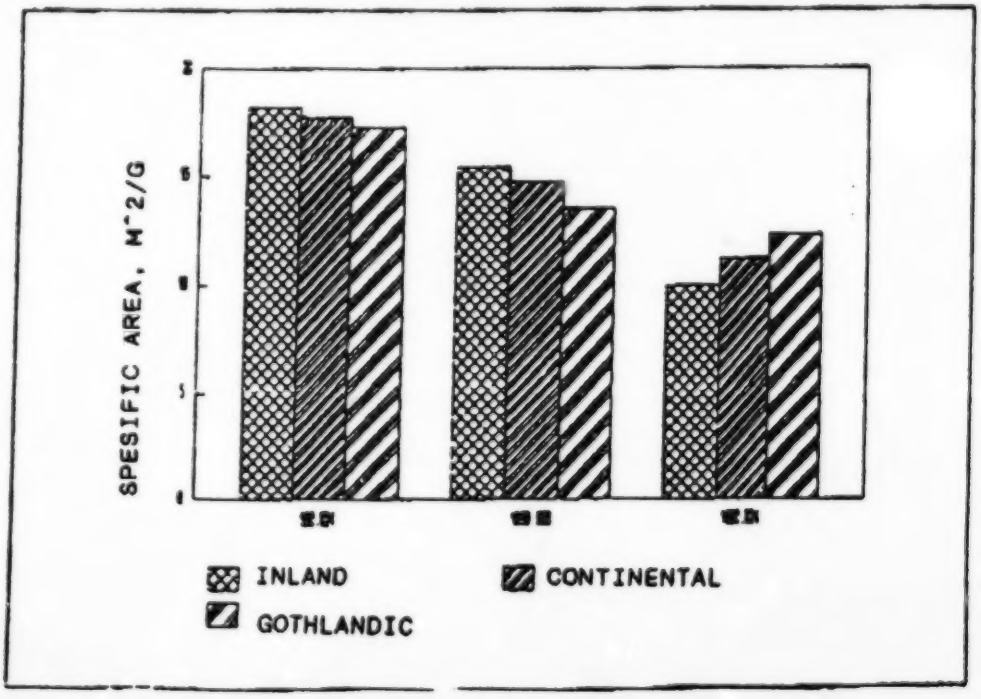
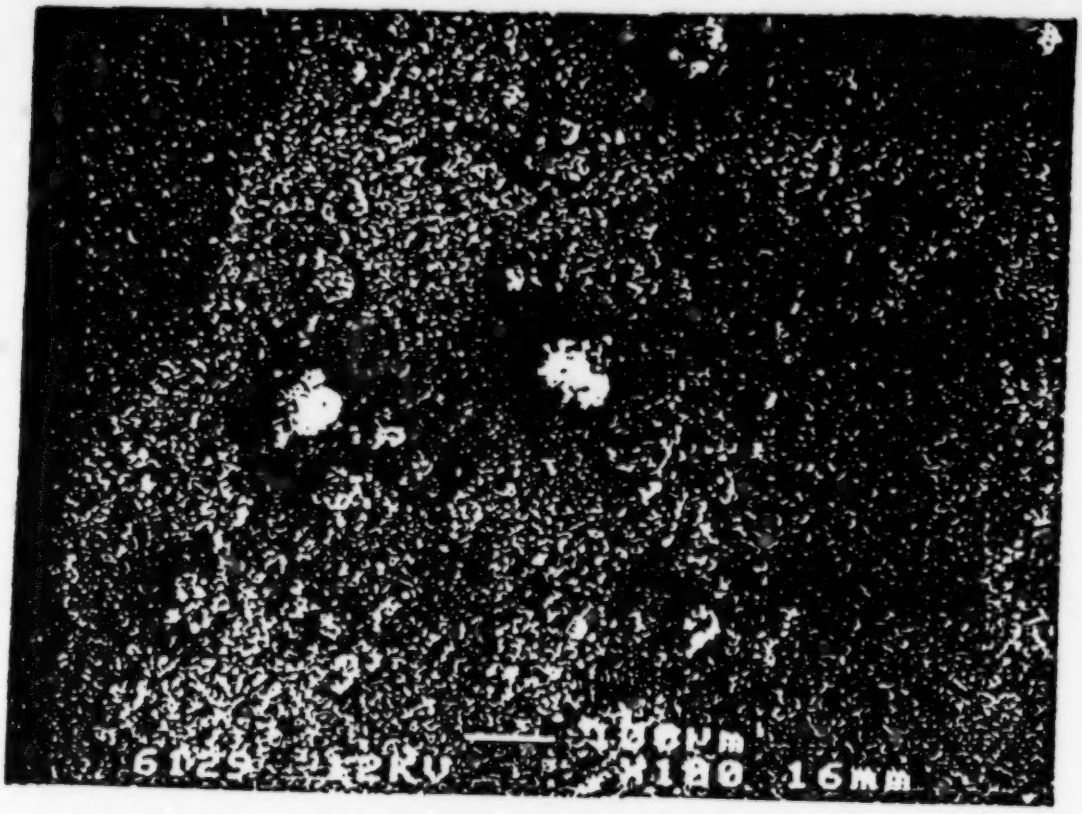


Fig. 4. Comparison of the spesific areas of limestones

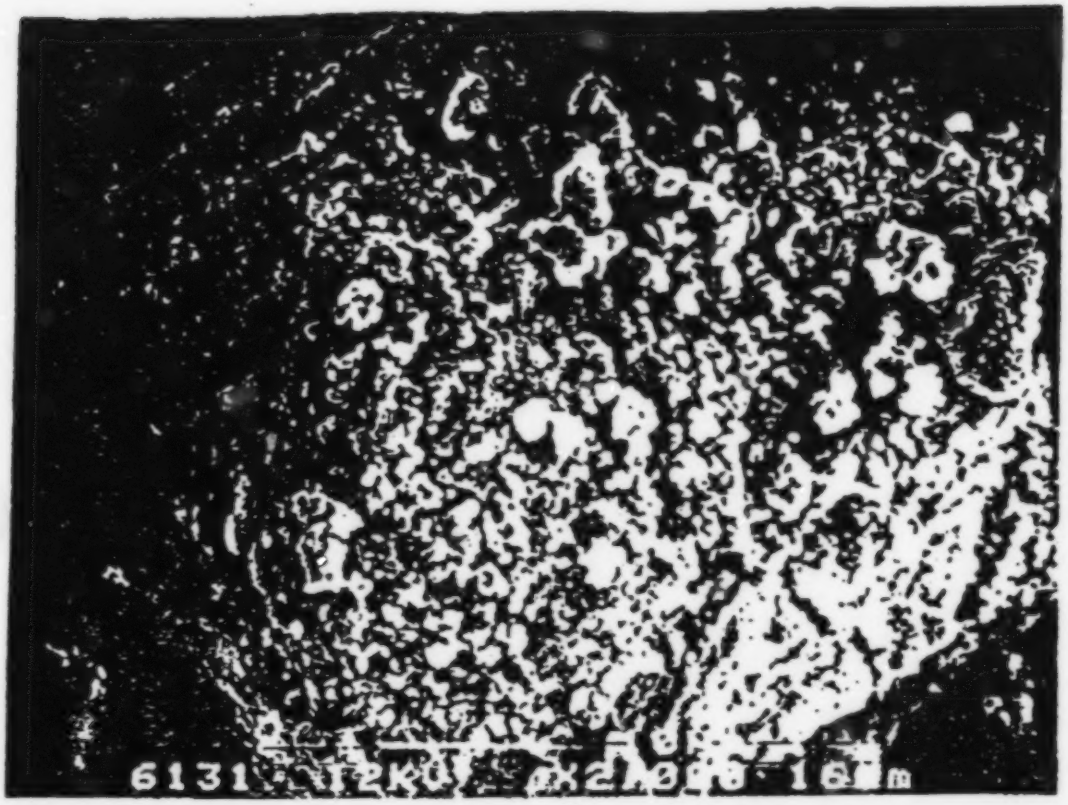
INLAND CEMENT, 1090 °C, 0.24 S

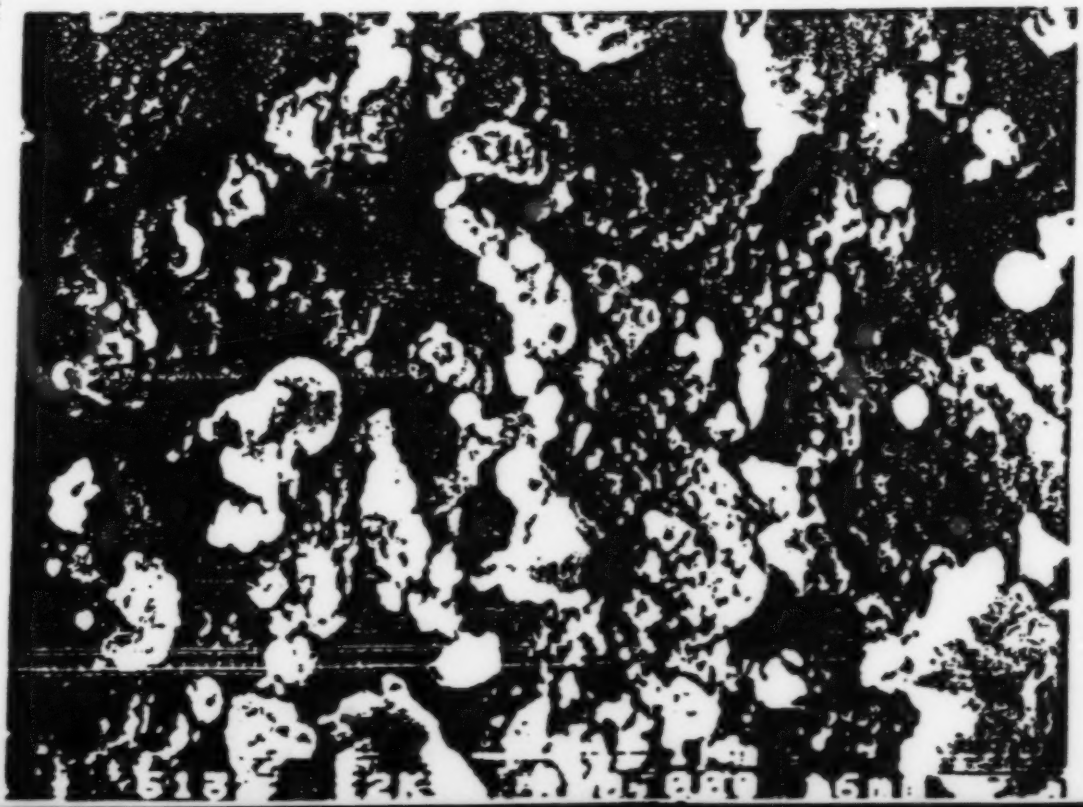
Appendix 7.



INLAND CEMENT, 1090 °C, 0.24 S

Appendix 8.



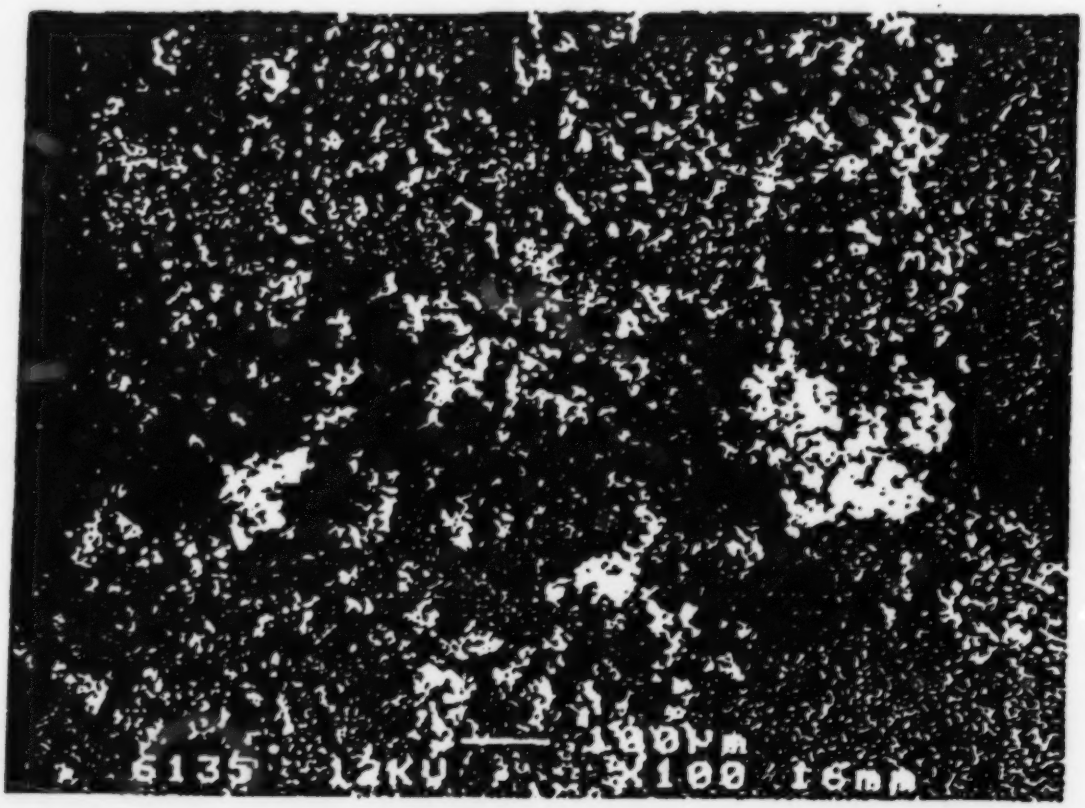


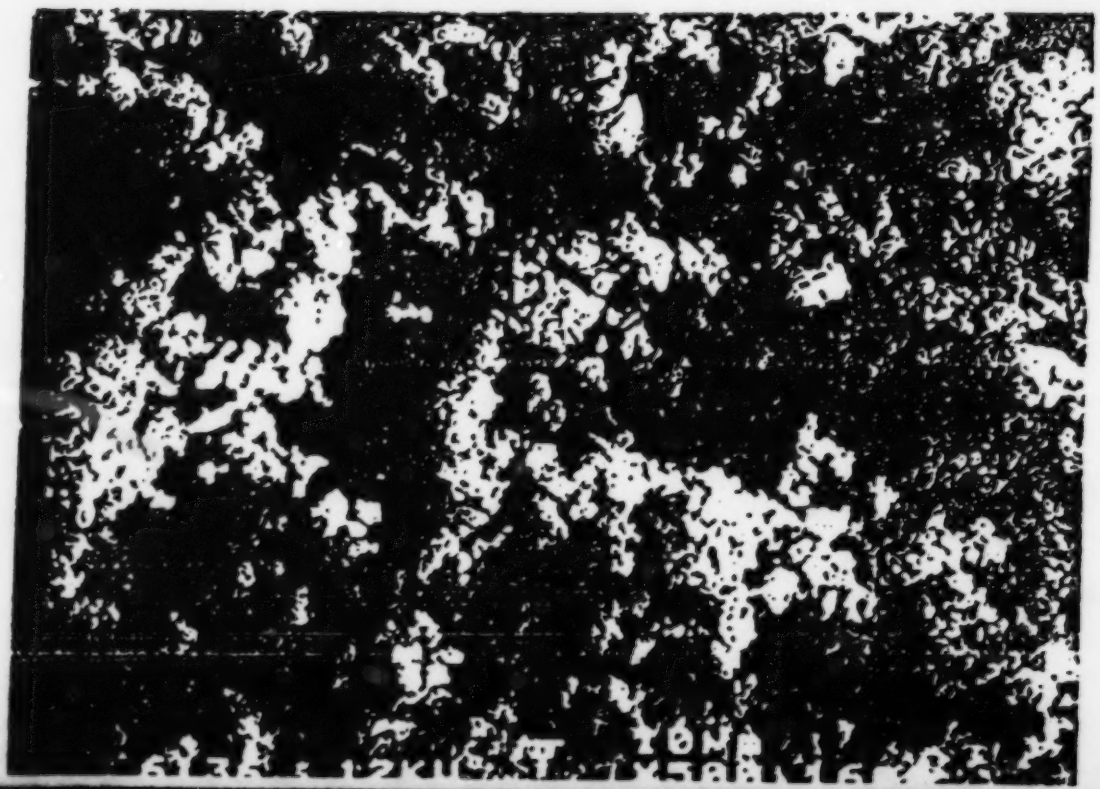
INLAND CEMENT, 1090 °C, 0.24 S

Appendix 9.

CONTINENTAL LIME, 1090 °C, 0.24 S

Appendix 10.





CONTINENTAL LIME, 1090°C, 0.24 s

Appendix 11.

CONTINENTAL LIME, 1090 C, 0.24 S

Appendix 12.